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Westech Engineering, Inc., Salem, OR

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DEMONSTRATION OF SERVICE LATERAL TESTING AND REHABILITATION TECHNIQUES

by

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Cooperative Agreement No. CS-811117

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This study was conducted in cooperation
with the City of Salem, Oregon

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16. ABSTRACT

The rehabilitation of sanitary sewers, significantly reducing infiltration/inflow has been difficult to achieve. A major reason for the disappointing I/I reductions achieved by many sewer rehabilitation efforts is the inability to satisfactorily locate and repair faulty service laterals. Service laterals are frequently major I/I contributors. The identification of I/I contributing service laterals is often difficult. Few methods and little equipment have been developed to either locate faulty service laterals or repair them. This project utilized and evaluated most service lateral testing, and repair methods used in the USA today. It also reports the costs and effectiveness of sewer rehabilitation where various combinations of main, manhole and service lateral repairs were employed. Repairs to service lateral piping included replacement, chemical grouting, installation of polyethylene pipe liners and installation of Insituform liners.

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance baetween human activites and the ability of natural systems to support and nurture life. The Clean Water Act, the Safe Drinking Water Act, and the Toxics Substances Control Act are three of the major congressional laws that provide the framework for restoring and maintaining the integrity of our Nation's water, for preserving and enhancing the water we drink, and for protecting the environment from toxic substances. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Water Engineering Research Laboratory is that component of EPA's Research and Development program concerned with preventing, treating, and managing municipal and industrial wastewater discharges, establishing practices to control and remove contaminants from drinking water and to prevent its deterioration during storage and distribution; and assessing the nature and controllability of releases of toxic substances to the air, water, and land from manufacturing processes and subsequent product uses. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Many municipal sanitary sewers are subject to infiltration of rainwater because of leaking joints and other defects that develop as sewers age. The result is excessive hydraulic loads on the sewage treatment plant during wet weather. Leaking service laterals are a previously-under-emphasized part of the problem. This report contains the result of an evaluation of a number of methods for testing and repairing service laterals.

Francis T. Mayo, Director
Water Engineering Research Laboratory

ABSTRACT

This demonstration project was initiated to further the knowledge of how to effectively rehabilitate sanitary sewers so that infiltration and inflow (I/I) are reduced or eliminated. Infiltration and inflow reduce the effectiveness of sewage treatment facilities, use capacities of sewers, lift stations and treatment facilities intended for community service and frequently result in surface water pollution, hazardous health conditions, public and household nuisances (flooding), and excessive costs.

The rehabilitation of sanitary sewers significantly reducing infiltration/inflow has been difficult to achieve. A major reason for the disappointing I/I reductions achieved by many sewer rehabilitation efforts is the inability to satisfactorily locate and repair faulty service laterals. Service laterals are frequently major I/I contributors. The identification of I/I contributing service laterals is often difficult. Few methods and little equipment have been developed to either locate faulty service laterals or repair them.

This project utilized and evaluated most service lateral testing and repair methods used in the USA today. It also reports the costs and effectiveness of sewer rehabilitation where various combinations of main, manhole and service lateral repairs were employed. Service laterals were accessed thru cleanouts, by excavation and pipe sectioning, and from within the main. TV inspections, air test and hydrostatic tests of service piping were made. Repairs to service lateral piping included replacement, chemical grouting, installation of polyethylene pipe liners and installation of Insituform liners.

This report was submitted in fulfillment of cooperative agreement CS-811117 by Westech Engineering, Inc. under the partial sponsorship of the U.S. Environmental Protection Agency and the City of Salem. This report covers a period from October 1981 to June 1984, and work was completed as of August 1985.

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LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviations

CI -- Cast Iron
CO -- Cleanout
EPA -- U.S. Environmental Protection Agency
gpd -- Gallons per Day
I/I -- Infiltration and Inflow
JT -- Joint
MGD -- Million Gallons per Day
MH -- Manhole
PE -- Polyethylene
PVC -- Polyvinyl Chloride
TV -- Television
ML/d -- Million Liters Per Day

Definitions

grout, grouting - (as used herein) a process for repairing faulty sewer pipes, manholes or service laterals with low viscosity chemical gels, usually acrilamides or polymers.

infiltration - groundwater which finds its way into a sanitary sewer thru faulty joints, cracks, etc.

inflow - stormwater which directly flows into a sanitary sewer thru connected roof drains or area drains, broken pipes, etc.

rainfall induced infiltration - stormwater and groundwater which rapidly saturates the materials around sewer piping and manholes during a storm event, and then infiltrates into the sewer system.

infiltration/inflow - storm and groundwater found in a sanitary sewer.

liner - a tube or lining placed inside a faulty pipe.

main - the public sewer located in the street or on an easement into which service laterals discharge (also known as street lateral).

mini-camera	-	a small diameter TV camera used for inspecting small sewer pipes.
service lateral	-	(also service, house connection or building sewer) the sewer pipe draining from a building into a sewer main.

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Tom Heinecke - Project Leader - Skyline
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Richard Beck - Manager
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and many others

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Jim Campbell - Engineering Technician
Ralph Borchert - Engineering Technician
Bill Sabo - Engineering Technician
and others

U.S. Environmental Protection Agency
Richard Field - Chief, Storm and Combined Sewer Program
Lam Lim - Chief, Technology & Standards Section

FINDINGS AND CONCLUSIONS

The Skyline and Missouri projects revealed a great deal about how to effectively repair sewer systems. Some lessons and conclusions are:

1. Sewer repairs should be done by sewer basin to reduce I/I. During wet weather, stormwater and groundwater gravitate into and collect in the backfilled sewer trenches. The granular bedding materials and pipe zone materials usually allow this water to move freely along the sewer trenches outside the sewer pipe. Even a few sewer faults can allow large amounts of this trench water to enter the sewers. This trench water can and often does flow into service lateral faults several feet from the main. Because the water moves easily along the old sewer trenches, repairing only the obvious leaks usually causes the level of the trench water to rise somewhat, thereby causing it to migrate into other sewer system faults.

2. The importance of repairing faulty service laterals was well demonstrated. If service laterals are faulty, particularly where faults are near the sewer main, repairing mains and manholes alone will do little to reduce peak I/I flows.

3. Sewer repair needs to be a comprehensive program. Flows from the basin selected for repair need to be measured during wet weather conditions before, during and after repairs are made so that the effectiveness of the repair program can be determined. The repair of all faults initially identified usually is not sufficient to greatly reduce I/I flows. Usually a few major undetected faults are discovered after initial repairs are made. When these faults are repaired, I/I flows are dramatically reduced.

4. Rubber ring jointed piping systems are usually easier and less expensive to repair than older mortar joint systems where more extensive repairs are necessary. Because of the granular backfills, some newer sewer systems contribute more I/I per foot of sewer main than do older more delapidated sewer systems.

5. Repairing sewer systems and effectively reducing I/I is challenging, difficult and demanding. To do it successfully requires both know-how and persistence.

6. Quality control is extremely important in repairing sewers. Many difficulties encountered in repairing the sewers in these two basins were caused by repair efforts, particularly chemical grouting work, which did not adequately seal the pipe and manhole faults.

7. There has been relatively little experience in testing, inspecting and repairing service laterals. The following observations about service lateral work are made:

   a. Locating faulty service laterals - smoke testing identified less than 10 percent of the faulty service laterals. TV inspecting sewer mains located most leaking service laterals when the work was done when groundwater levels are high. approximately 40 - 50 percent of the service laterals in the Skyline system leaked. Locating leaking service laterals by TV inspecting mains in newer rubber ring jointed piping systems appears reasonably efficient. In older mortar jointed sewer systems such as the Missouri system, nearly all service laterals leaked. Systematically air testing all service laterals or replacing or repairing all service laterals without first testing appears most feasible in this type of sewer system.

   b. Access for testing, inspecting and repairing - service lateral cleanouts for access have several advantages, the most important of which is that access for testing, inspection and repairs is available as needed over an extended period of time. Excavation and sectioning of service lateral piping usually affords the best access for testing, inspection and repairs. The excavation usually cannot be left open for an extended period of time and, consequently, all testing and repair work needs to be completed within a few days. This often is difficult to do. Access from within the sewer main using the Cues equipment requires no excavation and no contact with or consent from property owners. Only the downstream few feet of service lateral pipe can be entered, tested or repaired, however.

   c. Inspection and testing methods - the small diameter TV camera equipment provides a reasonably good visual inspection of service lateral pipes. Visual inspection is usually necessary to determine how repairs should be made. Several methods of leak testing service piping were used. The hydrostatic test is somewhat slow. Air testing from main to the service lateral cleanout is better, but does not locate the service leaks. The double ball air test unit provides rapid and accurate testing if a cleanout or excavation for access is available. This method locates pipe leaks, but cannot test the connection to the main. The Cues Lateral Sealing System tests the connection to the main, but cannot test farther than six or eight feet upstream.

d. Repair methods - no single repair method was found best for all service lateral installations. Each faulty service pipe installation had to be inspected and pipe conditions, configurations, depths and surface conditions were considered before a repair method was selected. In many cases, replacing service piping was least expensive and most desirable. Where the existing pipe was relatively straight, polyethylene liners were competitive in price with other repair methods and caused little disruption of surface facilities. The Westech/Gelco "snake" was best used where service piping is structurally sound, but a few joints leak. Grouting a few leaking joints is usually less expensive than other repairs. The Cues Lateral Sealing System is especially applicable where sewer mains are deep or inaccessible and where the service lateral piping is structurally sound. Insituform liners for service lateral repairs may in time become an excellent repair method. At this time, some technical problems must be resolved before this repair method can be widely used.

SECTION 1

INTRODUCTION

The Salem sewer system has been plagued for many years by excessive flows during wet-weather. High flows have been particularly critical after two or three days of heavy winter rain and have resulted in overloaded sanitary sewers, raw sewage bypasses, flooded basements, and overflowing manholes. Over the last two decades, Salem's Public Works Department has undertaken numerous projects to correct sewer system deficiencies. These efforts have mostly consisted of internally grouting sewer mains, and of replacing or lining deficient sewer mains. Some manhole repairs, but few service lateral repairs have been made. In a few cases, demonstratable flow reductions resulted.

Salem's experiences in reducing sewer system infiltration and inflow (I/I) by sewer rehabilitation are similar to the experiences of many other communities. Repairing mains alone has been done in many sewer systems, usually without reducing I/I flows much.

The technology of sewer rehabilitation is relatively new. TV inspection equipment has been available about 30 years and internal grouting equipment about 20 years. Although, over $3 billion has been spent in the last 10 years in the United States for evaluation and rehabilitation of sanitary sewer systems, few communities can show that significant I/I reductions resulted from the rehabilitation work. Most sewer rehabilitation work has been based on the hypothesis that repairing some sewer leaks, especially the larger leaks, will significantly reduce I/I. When scattered repairs are made to a leaking sewer system, groundwater levels tend to rise somewhat causing I/I to enter the sewer system at higher elevations or in other places. Often wet-weather sewer flows remain virtually unchanged after the scattered repairs are made. This phenomenon will be defined as "migration" or "hydraulic transfer."

I/I is caused by the availability of stormwater and groundwater and faults in the sewer system allowing that water to enter. In many sewer systems, there are far more faults than required to let all the available water to enter. Thus, as sewer rehabilitation takes place, often the faults in mains and manholes are first repaired. As these repairs restrict the flow of available water into the sewers, and as the groundwater levels adjacent to the sewers rise, small faults left unrepaired tend to allow more flow thru them because they are under greater hydrostatic pressure. Because many rehabilitation programs only make the easiest and most obvious repairs, migration and increased hydrostatic pressures frequently cause I/I flows to be nearly as large after rehabilitation as before.

Several communities have reported recently significant I/I reductions through the organized comprehensive rehabilitation of their sewers. The rehabilitation efforts most successful in eliminating I/I have been where almost all I/I sources have been systematically repaired. We know that if all system faults allowing I/I to enter that system are corrected, all I/I will be eliminated.

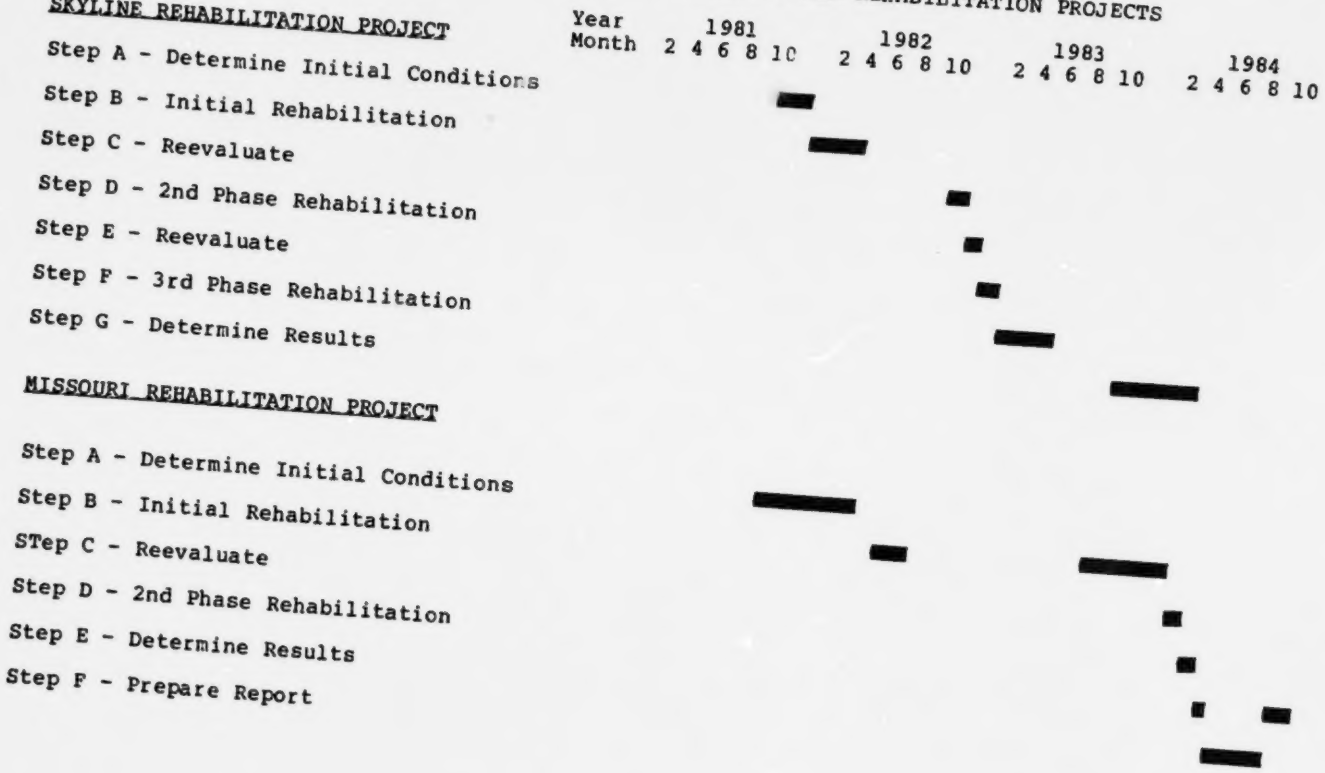
In 1981, City of Salem retained Westech Engineering and others to evaluate sewers in South Salem. High wet- weather flows in South Salem sewers had been a serious and growing problem for several years. Although City grouting crews had worked on many sewers in South Salem during the late 1970's, winter flows had not been dramatically reduced.

It was decided to rehabilitate two relatively small sewer basins and to carefully measure and document the work done, the flow reductions achieved, and the costs incurred. Both areas collected large I/I flows. The Skyline Sewer Rehabilitation Basin, a 67-unit subdivision adjacent to Skyline Road, was one such basin. Sewers in this area were built in the 1960's and were similar to much of the rubber ring-jointed concrete pipe in the South Salem system. Although most sewer mains in that basin had been previously grouted by City crews, peak wet weather I/I in 1982 was measured at 560,000 gpd (2.12 ML/d) with 411,000 gpd (1.56 ML/d) from the area rehabilitated. Subsequently, rehabilitation work including the repair of mains, manholes and service laterals reduced I/I flows by over 90%. The Skyline pilot rehabilitation program was Salem's first effort at systematically testing and repairing faulty service laterals. Service laterals in the Skyline Rehabilitation Basin contributed most of the I/I measured in 1982.

The Missouri Rehabilitation Basin is larger and more complex than the Skyline Basin. Sewers in this area serve 220 homes, and cover approximately 80 acres (32.37 Hectares). Most sewers in the Missouri Basin were installed in 1955-56 and are constructed of concrete mortar-jointed pipe similar to much other sewer piping installed in Salem between 1930 and 1958.

Although the Missouri Rehabilitation Basin was established in 1981, most rehabilitation work was not done until 1983-84. In 1981, information about system wet-weather flows, pipe conditions and groundwater conditions was collected. A depth x velocity flow meter was installed at the lower end of the Missouri Basin on February 20, 1982. It was maintained there during the winters of 1982-83 and 1983-84. In March 1983, an application was submitted to U.S. Environmental Protection Agency (EPA) by Salem and in September 1983, EPA awarded $100,000 as a demonstration cooperative agreement to enhance state-of-art sewer rehabilitation. The remaining two-thirds of the funds were budgeted by the City of Salem. Figure 1-1 shows a chronology of the projects.

FIGURE 1-1
CHRONOLOGY OF SKYLINE & MISSOURI SEWER REHABILITATION PROJECTS



SECTION 2

LOCATION, CLIMATE AND POPULATION

LOCATION

Salem is the state capital, Oregon's third largest city, and county seat of Marion County. Situated in the Central Willamette Valley, one of the most fertile and agriculturally productive regions in the world, Salem is located 47 miles (75.65 kilometers) south of Portland and 64 miles (103.00 kilometers) north of Eugene.

CLIMATE

Sheltered from extreme temperatures, the Willamette Valley enjoys a generally mild climate. Winter temperatures seldom fall below 25 degrees Fahrenheit and a typical summer day ranges from the mid to high 70's. Precipitation is mostly in the form of rain falling during the mild winter months between November and April. Over 70% of the annual precipitation falls during this five month period. Table 2-1 contains average climatic data for the city.

TABLE 2-1

SALEM CLIMATIC RECORD

MONTH	MEAN TEMP(^{o}F)*	AVE. MAX. TEMP(^{o}F)	AVE. MIN. TEMP(^{o}F)	MEAN PRECIP. (INCHES)**
JANUARY	38.9	45.5	32.2	6.40
FEBRUARY	42.8	51.1	34.5	4.93
MARCH	45.5	55.1	35.6	4.36
APRIL	49.7	60.9	38.4	2.30
MAY	55.5	67.9	43.1	2.01
JUNE	61.1	74.0	48.2	1.29
JULY	66.6	82.3	50.9	0.39
AUGUST	66.6	82.3	50.9	0.39
SEPTEMBER	62.0	76.4	47.5	1.57
OCTOBER	53.1	64.1	42.0	3.64
NOVEMBER	45.0	52.7	37.2	5.89
DECEMBER	41.1	47.4	34.8	6.97
ANNUAL	52.3	63.2	41.3	40.42

* F = 9/5 Celsius +32
** One inch = 2.54 cm

POPULATION

In 1982, Salem's population was 91,400. Approximately 125,000 people are served by the municipal sewer system.

SECTION 3

OBJECTIVES

The objectives of the two rehabilitation projects were not identical. The Skyline Rehabilitation Project was undertaken at a time when very little was known about the condition and configuration of service laterals, how to test or inspect them, or how to fix them. The Missouri Basin repairs were made nearly two years later when substantially more was known about service laterals and sewer rehabilitation generally.

For the Skyline Rehabilitation Project and the repair work which began in 1982, the objectives were to:

1. Determine the I/I contribution of service laterals.

2. Determine the typical problem features in service lateral piping.

3. Seek ways to better control service lateral construction and to insure that watertight service laterals are maintained.

4. Seek ways to effectively rehabilitate leaking service laterals.

5. Measure the percentage of I/I removed by mainline grouting only, and by mainline grouting and service lateral rehabilitation together.

6. Establish preliminary data for the cost of rehabilitation vs. I/I removed in rubber gasketed concrete sewer piping typically found in the Salem sewer system.

By late 1983 when rehabilitation work on the Missouri Rehabilitation Project began in earnest, not only had the Skyline Project been completed, but other rehabilitation projects involving the testing and repair of service laterals had been completed by Gelco and Westech. Thus, the techniques and the equipment for dealing with service laterals had advanced considerably between early 1982 and late 1983. Consequently, the objectives of the Missouri Rehabilitation Project were:

1. To demonstrate the costs and cost-effectiveness of "complete" rehabilitation involving the testing and repair of most mains, manholes and service laterals in a basin

versus rehabilitation of mains and manholes only or rehabilitation of mains, manholes and the "public" portion of service laterals only.

2. To further develop, test, demonstrate and evaluate various techniques and equipment for service lateral testing and repair work.

3. To reduce I/I flows in the Missouri Basin.

The mortar-joint concrete sewer piping in the Missouri Basin is typical of Salem's older mortar-jointed concrete sewers. Therefore, information about the types of installations discovered, the problems encountered, the lessons learned, and the costs incurred, would guide other rehabilitation projects.

SECTION 4

SKYLINE REHABILITATION PROJECT

A. DESCRIPTION OF BASIN

In 1981, a decision was made to conduct and document rehabilitation efforts in the "Skyline Rehabilitation Basin." This basin was chosen for study because:

1. All of the sewers drained to a common point where monitoring flows could be done relatively easily.

2. The sewers were known to contribute major I/I flows.

3. The sewers, topography, and neighborhood are typical of the parts of South Salem built since 1963.

4. Most sewer mains are 8 in. (20.32 centimeters) diameter.

5. The rehabilitation basin was about the right size for the funds available.

The Skyline Rehabilitation Basin is a residential area, 67 houses and an 8 unit apartment complex. The area is served by 2,584 ft (788 meters) of rubber ring jointed concrete pipe constructed between 1964 and 1966, and 745 ft (277 meters) of PVC pipe constructed in the late 1970's. All streets are paved and curbed. Most sewer mains lie beneath the streets where the sewer ditches were backfilled with gravel. The area is hilly with moderate slopes and with red silt clay soils of low permeability. Most lots drain towards the streets, which have catch basins and piped storm drainage systems. All homes are ranch style without basements. The basin, sewers and topography are shown on Figure 4-1.

B. REHABILITATION PROCESS

The rehabilitation process began in the Fall of 1981. Table 4-1 lists project activities, and Figure 4-1 shows the study area, rehabilitation basin, repairs made during various rehabilitation steps, and peak I/I measured before and after rehabilitation. Initial investigations determined that some sewers contributed little I/I. Rehabilitation was, therefore, limited to the ten sections of sewer pipe found to be

FIGURE 4-1

- CITY OF SALEM -

SKYLINE REHABILITATION AREA

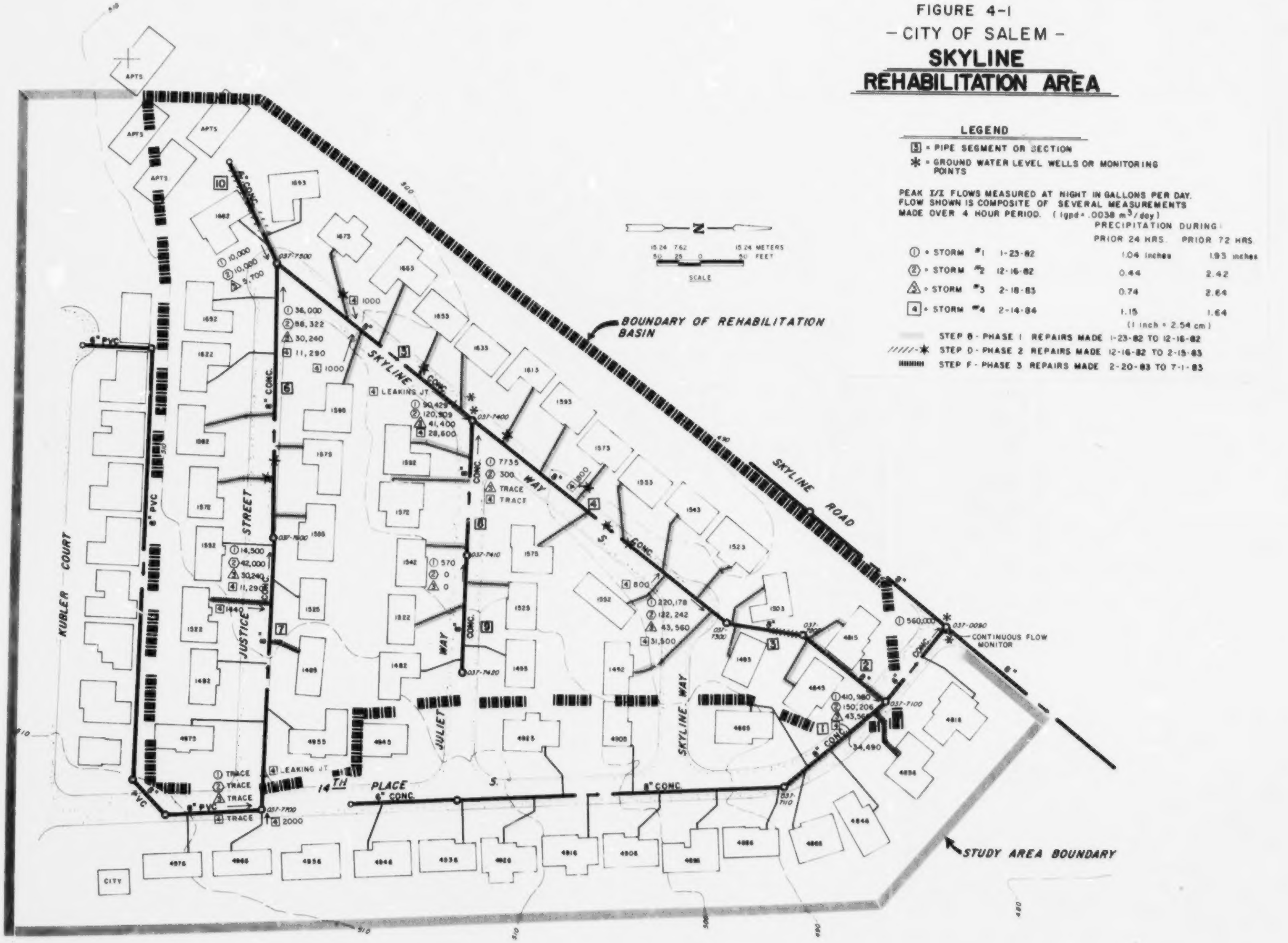

LEGEND
5 = PIPE SEGMENT OR SECTION
* = GROUND WATER LEVEL WELLS OR MONITORING POINTS
PEAK I/I FLOWS MEASURED AT NIGHT IN GALLONS PER DAY. FLOW SHOWN IS COMPOSITE OF SEVERAL MEASUREMENTS MADE OVER 4 HOUR PERIOD. (1gpd = .0038 m³/day)
PRECIPITATION DURING:
PRIOR 24 HRS. PRIOR 72 HRS
① = STORM #1 1-23-82 1.04 inches 1.93 inches
② = STORM #2 12-16-82 0.44 2.42
③ = STORM #3 2-18-83 0.74 2.64
④ = STORM #4 2-14-84 1.15 1.64
(1 inch = 2.54 cm)
STEP B - PHASE 1 REPAIRS MADE 1-23-82 TO 12-16-82
/////-* STEP D - PHASE 2 REPAIRS MADE 12-16-82 TO 2-15-83
IIIIIIII STEP F - PHASE 3 REPAIRS MADE 2-20-83 TO 7-1-83
N
15.24 7.62 0 15.24 METERS
50 25 0 50 FEET
SCALE
BOUNDARY OF REHABILITATION BASIN
STUDY AREA BOUNDARY
SKYLINE ROAD
SKYLINE WAY S.
SKYLINE WAY
JUSTICE STREET
JULIET STREET
JUSTICE WAY
14TH PLACE S.
KUBLER COURT
CONTINUOUS FLOW MONITOR
037-0090
037-7100
037-7110
037-7300
037-7400
037-7410
037-7420
037-7500
037-7600
037-7700
① 560,000
① 410,980
② 150,206
③ 43,560
34,490
① 220,178
② 122,242
③ 43,560
④ 31,500
④ 800
④ 1800
① 7735
② 300
③ TRACE
④ TRACE
① 90,429
② 120,909
③ 41,400
④ 28,600
④ LEAKING JT.
④ 1000
① 36,000
② 88,322
③ 30,240
④ 11,290
① 10,000
② 10,080
③ 5,700
① 14,500
② 42,000
③ 30,240
④ 11,290
④ 1440
① 570
② 0
③ 0
④ LEAKING JT.
① TRACE
② TRACE
③ TRACE
④ TRACE
④ 2000
8" CONC.
6" CONC.
8" PVC
6" PVC
APTS
CITY

TABLE 4-1
CITY OF SALEM
SKYLINE REHABILITATION ACTIVITIES

STEP A Measure Initial Conditions	STEP B Phase I Rehabilitation	STEP C Measure Post Rehab. Conditions	STEP D Phase 2 Rehabilitation	STEP E Measure Post Rehab. Conditions	STEP F Phase 3 Rehabilitation
1) Monitor basin flows	1) Grout all sewer main joints found leaking in Sec.'s 1, 2 and 10	1) Monitor basin flows	1) Grouted 18 main joints in Sec.'s 3,6 and 10	1) Monitor basin flows	1) Repair 2 service laterals in Sec. 7
2) Measure peak wet-weather flows at all access points	2) Repair all leaking service laterals in Sec.'s 2, 3, 4, 5, 6, 8 & 9	2) Measure peak wet-weather flows at all access points	2) Regrouted 4 manholes	2) Measure peak wet-weather flows at all access points	2) Repair 1 service lateral in Sec. 1
3) Monitor ground-water levels	3) Repair all leaking manholes	3) Monitor ground-water levels	3) Regrouted 5 service laterals in Sec.'s 4, 5 & 6	3) Monitor ground-water levels	
4) Map all mains and service laterals		4) TV inspect mains			
5) TV inspect mains					
6) Smoke test all sewers					
7) Air test w/packer all main pipe jts.					
8) Measure peak manhole leakage					
9) Measure service lateral flows					
10)Air test service laterals					

contributing significant I/I flows. Most sewer mains had been previously grouted by City crews during the previous few years.

The first step was to establish initial conditions - Step A on the activities schedule. This consisted of the following tasks:

Step A

Flow Monitoring--

In the fall of 1981, a depth x velocity continuously recording flow meter was installed in Manhole 037-0090. This flow meter monitored flows from the entire study area during the winters of 1981-82 and 1982-83. These flow recordings are shown on Figure 4-2.

Groundwater Level Measurements--

Four groundwater monitoring stations were established, two in the sewer trench at manholes 037-0090 and 037-4400 and two others nearby in undisturbed native soils. The groundwater levels were measured periodically during the rehabilitation process.

TV Inspections and Joint Tests--

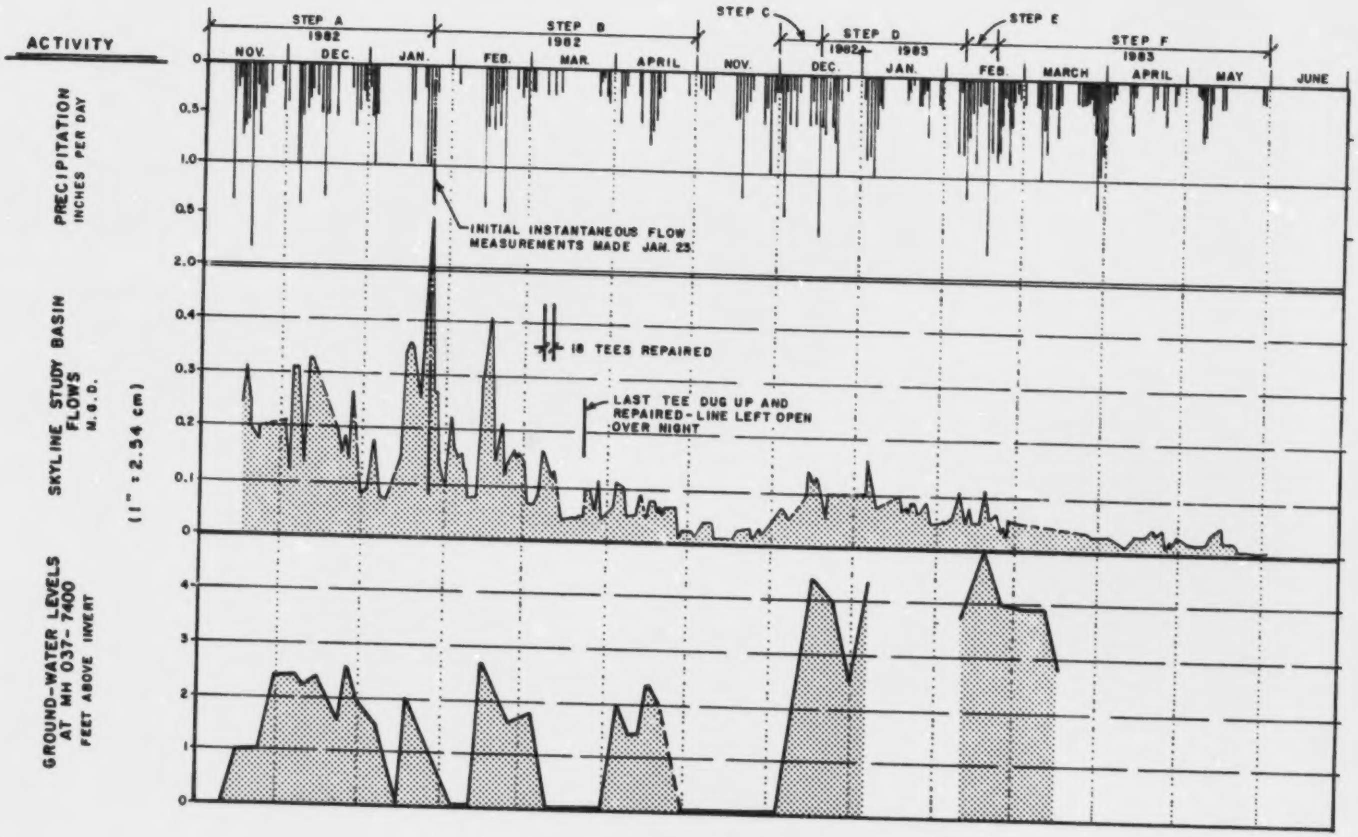
All sewer mains within the rehabilitation basin were systematically TV inspected and all joints were air tested using an inflatable packer normally used for grouting work. All but Section 10 had previously been tested and grouted. Records showed that 179 faulty joints had been grouted in pipe segments 1-9 during that earlier work. The Step A joint tests found only four faulty joints in segments 1-9 and 11 faulty joints and sheared pipes in segment 10.

Smoke Tests--

City crews smoke tested all sewers within the study area. Smoke tests revealed just one service lateral leak. Smoke testing consists of blowing non-toxic smoke into an isolated portion of a sewer system and then searching for eminating from roof drains, storm sewers, the ground or other places where faulty sewer piping is indicated.

Peak Wet-Weather Flow Measurements--

On January 23, 1982, Salem was in the midst of a severe Pacific storm which dropped approximately 2 in. (5.08 centimeters) of rain over a three day period. Storms of this magnitude usually occur several times each winter. During this storm period, peak wet-weather flows contributed by each section of sewer pipe, and the I/I contributions of service laterals and manholes were measured.



STUDY BASIN FLOWS
SKYLINE REHABILITATION PROJECT

FIGURE 4-2

The I/I contributions of various pipe segments were measured by entering each manhole within the rehabilitation basin at night between midnight and 6:00 a.m. when actual sewage contributions were minimal. Flows were measured at each access point at least four times during this period. The results were averaged forming the measurements shown on Figure 4-2.

During the day of January 23, each manhole within the area of concentrated study was plugged on each side, the water level was allowed to rise within each leaking manhole, that water was then pumped into a bucket and measured. The manhole I/I contributions were thereby determined. Although there were several manholes which leaked, no manhole contributed significant I/I.

A similar effort was made to measure service lateral I/I contributions. A special apparatus (shown in Figure 4-4) was built to measure service lateral flows. This appartatus consisted of a mainline packer together with a self-leveling weir box which could be viewed through a closed circuit TV camera. On January 23rd, the flows from service laterals on pipe sections 2, 3, 4, 5, 6, 8 and 9 were measured. This effort continued for several days and was completed on January 27. These measurements were only marginally successful. The apparatus measured flows up to 10 gpm (37.85 liters per minute) with good accuracy, but some service laterals contributed peak I/I flows over 50 gpm (189.27 liters per minute). These flows simply could not pass through the equipment. Also, it took several days to measure all service lateral flows. The service lateral I/I contributions varied tremendously over this period. For instance, the service lateral I/I flow at 1653 Skyline Way was measured at 5 gpm (18.93 liters per minute) on January 23rd, but only 0.5 gpm (1.89 liters per minute) on January 26. Thus, unless the flows from all service laterals can be measured within a short time period, it is very difficult to correlate the measurements with overall system flows.

Test Service Laterals for Leakage--

Permission was obtained from all property owners within the study area to test and repair private service piping. All work was done at no expense to the property owners involved. Service lateral piping was located adjacent to each house. Most service laterals had existing cleanouts within a few feet of each building. Only a few of those cleanouts could be used for pipe testing, however, and only four of the existing cleanouts proved useable for service lateral TV inspections. In most cases, City crews installed new cleanouts (see Figure 4-3) adjacent to buildings before the testing and inspection of service lateral pipes could begin.

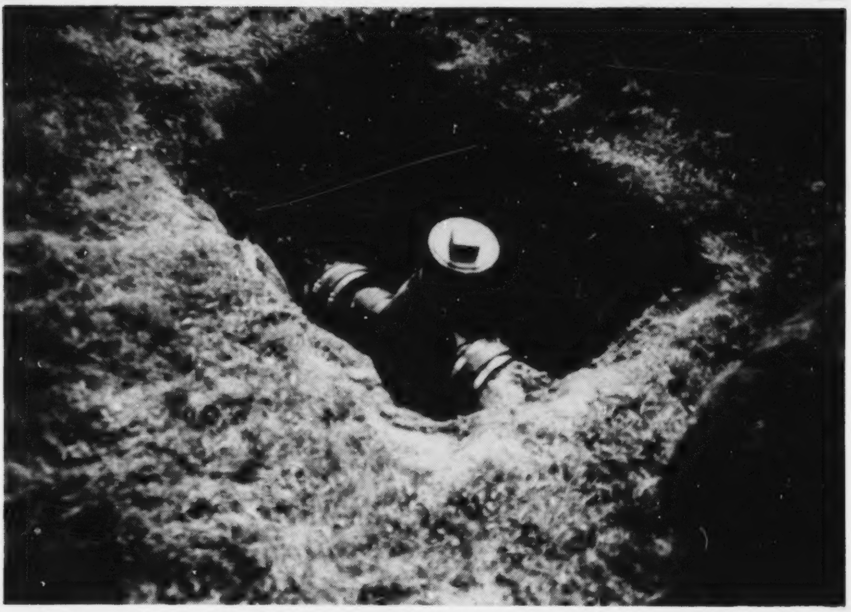


Figure 4-3 - Typical cleanout installed on existing service lateral.

Figure 4-4 - Apparatus for measuring service lateral flows.

TABLE 4-2
SKYLINE REHAB. AREA
SERVICE LATERAL INFORMATION

				Leakage Noted By			Conditions Found				Repairs Made			
Pipe Sec.	Address	Length (ft)	Type Pipe	Smoke Test	TV Insp. if Main	Air Test	New Clean-Out	Tee or 1st Jt Break	Jt Leaks	Other	Grout Tee or 1st Jt	Grout Other Jts	Dig up & Repair	Notes
1.	4885 14th Pl.	---	Concrete	NO	NO	---	NO	---	---	---	---	---	---	---
	4866 14th Pl.	---	Concrete	NO	NO	---	NO	---	---	---	---	---	---	---
	4846 14th Pl.	---	Concrete	NO	NO	---	NO	---	---	---	---	---	---	---
	4836 14th Pl.	---	Concrete	NO	YES	---	YES	---	---	---	---	---	---	REPAIRED STEP F
2.	4845 14th Pl.	49	Concrete	NO	YES	---	YES	YES	NO	NONE	YES	NONE	NO	STEP B
	4815 14th Pl.	39	Concrete	NO	YES	---	YES	YES	NO	NONE	YES	NONE	NO	STEP B
3.	1493 Skyline	30	Concrete	NO	YES	YES	YES	YES	YES	NONE	YES	4	NO	STEP B
	1503 Skyline	52	Concrete	NO	YES	YES	YES	YES	YES	NONE	YES	5	NO	STEP B
4.	1492 Skyline	110	Concrete	NO	NO	YES	YES	NO	NO	NONE	NO	NONE	NO	NO REPAIR SMALL LEAK
	1523 Skyline	52	Concrete	NO	YES	YES	YES	YES	YES	BEND @ PL	YES	5	NO	STEP B
	1552 Skyline	55	Concrete	NO	YES	YES	YES	YES	YES	BEND @ PL	YES	2	YES @ PL	REPLACED BEND AT PL - STEP B
	1543 Skyline	60	Concrete	NO	NO	YES	YES	YES	YES	NONE	YES	4	NO	STEP B
	1553 Skyline	60	Concrete	NO	YES	YES	YES	YES	YES	BEND @ PL	YES	4	NO	STEP B
	1573 Skyline	50	Concrete	NO	YES	YES	YES	YES	YES	BEND @ PL	YES	2	GROUTED 21 FT FROM TOWARDS HOUSE	MAIN - STEP B - REP'D AGAIN - STEP D
	1593 Skyline	60	Concrete	NO	YES	YES	YES	NO	YES	BEND @ PL	NO	3	GROUTED 21 FT FROM TOWARDS HOUSE	MAIN - STEP B
	1613 Skyline	72	Concrete	NO	YES	YES	YES	YES	YES	NONE	YES	3	NO	STEP B - REPAIRED AGAIN STEP D
	1575 Juliet	67	Concrete	NO	YES	YES	YES	YES	NO	BROKEN TEE-	YES	NONE	YES @ TEE	REPLACED TEE CONNECT. & MAIN-STEP B
5.	1633 Skyline	65	Concrete	YES	YES	YES	NO	YES	YES	BEND @ PL	YES	GROUTED 30 FT FROM		MAIN TOWARDS HOUSE - STEP B
	1653 Skyline	60	Concrete	NO	YES	YES	YES	YES	YES	BEND @ PL	YES	GROUTED 30 FT FROM		MAIN TOWARDS HOUSE - STEP B - REPAIRED AGAIN - STEP D
	1663 Skyline	70	Concrete	NO	NO	YES	YES	YES	NO	NONE	YES	NONE	NO	STEP B
	1673 Skyline	65	Concrete	NO	NO	YES	YES	YES	NO	NONE	YES	NONE	NO	STEP B, REPAIRED AGAIN - STEP D
	1595 Justice	66	Concrete	NO	NO	YES	YES	YES	YES	BEND @ PL	YES	0	YES	REPLACED FROM 15 FT INSIDE PL TO MAIN-LINE - STEP B
6.	1652 Justice	---	PVC	NO	NO	NO	NO	NO	NO	NONE	NO	NONE	NO	
	1622 Justice	---	PVC	NO	NO	NO	NO	NO	NO	NONE	NO	NONE	NO	FAILED AIR TEST BUT FOUND NO LEAK - STEP B
	1592 Justice	80	PVC	NO	NO	YES	NO	NO	YES	NONE	NO	NONE	NO	
	1572 Justice	63	PVC	NO	YES	YES	YES	YES	YES	NONE	YES	1	NO	STEP B - REPAIRED AGAIN - STEP D
	1575 Justice	34	Concrete	NO	NO	YES	YES	NO	YES	BEND @ PL	NO	4	NO	STEP B
	1555 Justice	39	Concrete	NO	NO	YES	YES	YES	NO	NONE	YES	NONE	NO	STEP B
7.	4975 14th Pl.	---	Concrete	NO	NO		NO	---	---	---	---	---	---	---
	1482 Justice	---	Concrete	NO	NO		NO	---	---	---	---	---	---	---
	1522 Justice	---	Concrete	NO	YES*		YES	---	---	---	---	---	---	REPAIRED STEP F
	1525 Justice	---	Concrete	NO	NO		NO	---	---	---	---	---	---	---
	1485 Justice	---	Concrete	NO	YES*		yes	---	---	---	---	---	---	REPAIRED STEP F
	1525 Justice	---	Concrete	NO	NO		NO	---	---	---	---	---	---	---

8.	1542 Juliet	46	Concrete	NO	NO	YES	YES	NO	YES	BEND @ PL	NO	1	NO	NO
	1572 Juliet	85	Concrete	NO	NO	YES	YES	NO	YES	BEND @ PL	NO	2	NO	NO
	1592 Juliet	70	Concrete	NO	YES	YES	YES	YES	YES	BEND @ PL	YES	5	NO	NO
9.	1482 Juliet	---	Concrete	NO	NO	NO	YES	NO	NO	NONE	NO	NONE	NO	NO
	1522 Juliet	60	Concrete	NO	NO	YES	YES	NO	YES	BEND @ PL	NO	0	NO	NO
	1495 Juliet	48	Concrete	NO	NO	YES	YES	NO	YES	BEND @ PL		NONE	NO	NO REPAIR - SMALL LEAK
	1525 Juliet	50	Concrete	NO	NO	YES	YES	NO	YES	BEND @ PL	NO	1	NO	NO
10.	1682 Justice	---	Concrete	NO	NO	---	YES	---	---	---	---	---	---	---
	1693 Skyline	---	PVC	NO	NO	---	NO	---	---	---	---	---	---	---

* I/I observed by TV inspection only after Step B repairs made.

PL = Property Line

(Ft x .304801 = Meters)

In pipe sections 2, 3, 4, 5, 6, 8 and 9 all service lateral pipes were systematically tested from the sewer main to the cleanout adjacent to the buildings. This was done by inserting a plug down the cleanout into the upper end of the service lateral pipe and by placing a mainline packer over the tee in the main. The packer was then expanded and an air test was made on the entire service lateral. Of the 31 service laterals tested, 28 failed the air test. Parallel hydrostatic water tests were run on each service lateral using the packer to contain the water at the lower end of the service lateral and filling the service lateral to the top of the cleanout. In all but one case, the hydrostatic tests gave results identical to the air tests. The air tests, however, were much quicker and easier to run. Table 4-2 summarizes the results of the service lateral tests.

Step B, Phase 1 Rehabilitation Work

Mainline Repairs--

The leaking mainline joints in sections 1, 2, and 10 were to be grouted. This was done, except that the packer stuck in section 10 and only five of the 11 leaks were actually grouted. One joint leak in section 3 was left unrepaired on purpose.

Manhole Repairs--

All leaking manholes were drilled and grouted until it was visibly determined that leakage had stopped.

Service Lateral Repairs--

All service laterals in sections 2, 3, 4, 5, 6, 8, and 9 were systematically repaired. This effort began by TV inspecting each service line. A 1.5 in. (3.81 centimeters) TV camera (See Figure 4-6) was rodded through the cleanout adjacent to the house and down each service lateral to visibly inspect it. Many service laterals had a series of bends at or near the property line, which made access to the portion beneath the street difficult. The TV inspections revealed that virtually all service lateral piping was structurally sound and that only a very few root intrusions existed. The inspections also revealed some very large service lateral leaks in piping within a few feet of the sewer main.

With that information, it was decided to air test the connections at the main and the service lateral piping 3 to 5 ft (0.92 meters to 1.52 meters) upstream of the main. This was done by washing a 4 in. (10.16 centimeters) inflatable plug with a long hose (Figure 4-5) attached down each service lateral until it popped out into the main where it could be viewed with the TV camera. Then the plug was pulled back 3 to 5 ft (0.92 meter to 1.52 meters) inside the service piping, and was expanded. The mainline packer was then positioned over the tee, was expanded,

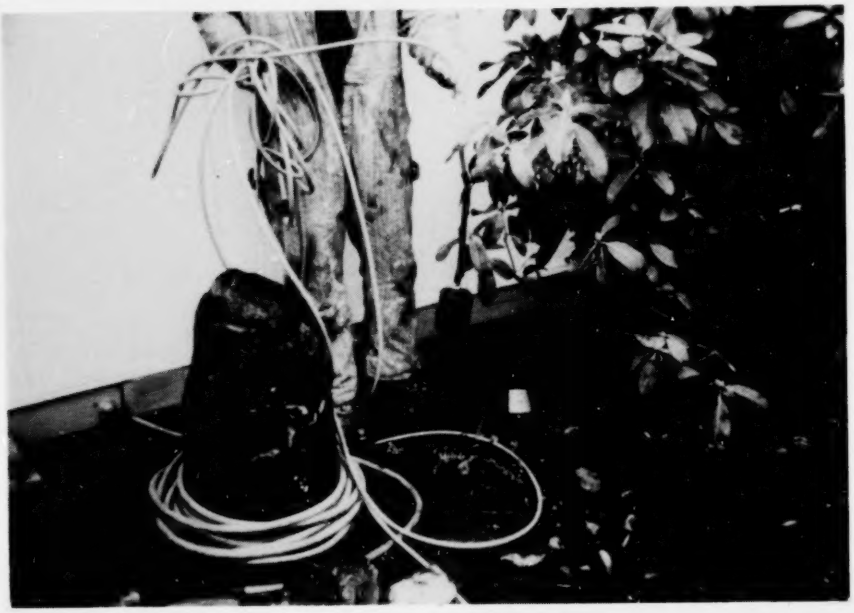


Figure 4-5 - Long stem plug used for air testing service laterals.

Figure 4-6 - Miniature TV camera used for inspecting service laterals.

and the pipe between was air tested. Nineteen of 28 tees tested, leaked. Eighteen of the 19 were repaired by simply pumping grout into the first couple of feet of service pipe with a 4 in. (10.16 centimeters) plug in place as described (Method A). The plug was then pulled out of the service lateral, and a hydraulic cleaner was inserted to clean the excess grout from the service lateral piping. The plug was then washed back down the service lateral, and the repair retested. Some leaks at or near the main were very large I/I contributors. Fifteen of the 19 service laterals with leaking tees also had leaks upstream.

Next, repair of a number of the remaining leaking service laterals was made by using a new device. Nicknamed the "snake", this device had been developed precisely for the internal grouting of service lateral pipes. It consists of a flexible rubber inflatable tube, with a mechanism to propel it down service lateral piping from a service line cleanout. The apparatus crawls through service lateral piping, around minor bends, isolates sections of service lateral piping, air tests the isolated sections, and grouts leaks which are found. See Figure 4-7.

Thirteen services were repaired from cleanout to main by sending the snake down through the house cleanout. Several services have bends near property lines which prevented snake access to the lower portions of the service lateral. In six service laterals, the lower portions under the street were repaired by pumping the no access portions of the line full of grout and then cleaning the excess grout out (Method B). Three services were dug up for various reasons. About 30 ft (9.14 meters) of one service lateral was replaced, and fittings were replaced on two other services. Table 4-3 shows work done on the 28 service laterals which failed the air test.

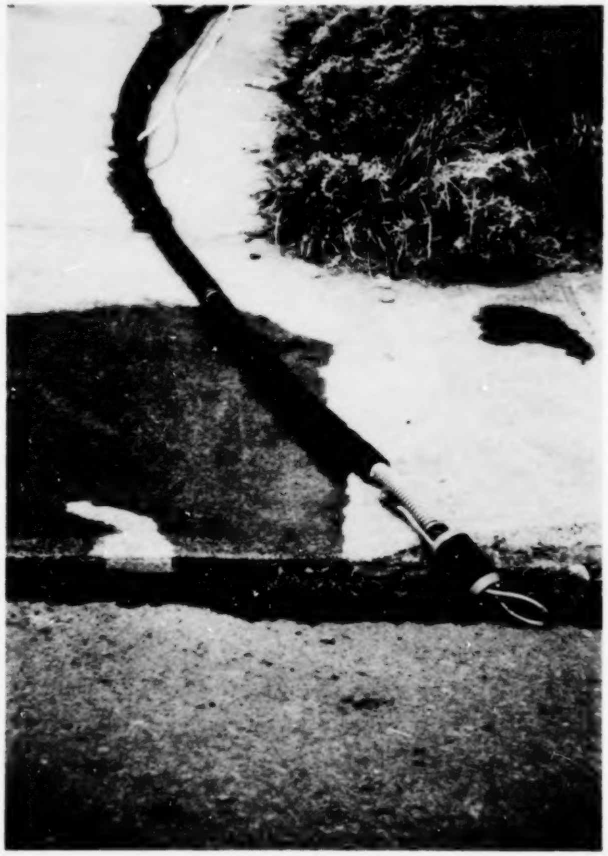


Figure 4-7

The "Snake" - self-propelled apparatus which crawls into service piping through a cleanout, and which is used to systematically air test piping and grout leaks.

TABLE 4-3

The following actions were taken on the 28 service laterals found leaking by air testing:

Action	Number of Service Laterals
Repaired by grouting tee alone.	4
Repaired entire service with snake.	6
Grouted tee and fixed rest of service with snake.	7
Fixed upper part of service with snake and repaired lower part and tee by pumping line full of grout.	6
Dug up at main and at bend on private property. Made 2 repairs and fixed rest with snake.	1
Replaced from main to 15ft (4.57 m) inside property line. Fixed rest with snake.	1
Did not repair because of very small leakage and difficult repair conditions.	2
TOTAL	28

Step C - Measure Post-Rehabilitation Conditions

The initial repairs were completed in the Spring of 1982. In December 1982, peak wet-weather flows were measured during several storm periods with the same techniques used earlier. A storm on December 16, 1982, was considered comparable to the initial storm. The peak flows measured are shown on Figure 4-1. A peak flow of 150,000 gpd (0.568 ML/d) was measured at Manhole 037-7100 compared to the pre-rehabilitation flow of 411,000 gpd (1.556 ML/d). Although I/I flows apparently had been reduced by 63%, these results were disappointing.

Pipe segments 1-10 were again TV inspected. Three leaking service laterals in pipe segments 1 and 7 had purposely not been repaired in Step B. These three service laterals were contributing large I/I flows, an estimated flow of 62,000 gpd (0.234 ML/d). The TV inspections also revealed that seven of the service laterals previously repaired still leaked, that four manholes previously repaired were again leaking, and that one pipe joint had apparently developed a very large leak. The pipe joint had previously been tested on several occasions and had always been found watertight.

Step D - Phase II Rehabilitations

Again, mainline joints were tested in suspect areas. The sewer pipe in section 3 has a significant grade dip which made it difficult to position the packer over the pipe joints. As flow measurements indicated a leak in section 3, ten joints were grouted. The flows were reduced. One joint in section 6 and 4 shears and a hole in section 10 were repaired. Of the ten services found leaking during the TV inspections, three were again purposely not repaired. Five were repaired using the snake, and two were left unrepaired because we were unable to get permission again from those property owners to work on their properties. Fortunately, those two services were not leaking badly. In each of the five services repaired the second time, leaks were found in only one small area, and each of the repairs at or near the mainline was found to be watertight.

Step E - Post-Rehabilitation Conditions

Peak wet-weather flows were measured again during two storm periods in February 1983. The storm of February 18, 1983 was considered comparable to the storms of January 23, 1982 and December 16, 1982. The peak flow measured at Manhole 037-7100 was 43,560 gpd (0.165 ML/D), of which 30,240 gpd (0.114 ML/d) was generated in section 7 where two leaking services purposely had not been repaired.

Step F - Phase III Repairs

The three leaking service laterals, one in section 1 and two in section 7, were repaired in May and June of 1983. Cleanouts were installed and the snake was used to test and repair from the cleanout to the main. Peak wet-weather flows were measured in December 1983 and February 1984 to determine the effect of these repairs.

The peak I/I flow measured at Manhole 037-7100 was now 34,500 gpd (0.131 ML/d). Most (72%) of this flow was entering sections 5 (39%) and 7 (33%). TV inspections made immediately after the flows were measured revealed:

> Section 5 - three services leaking and one main joint leak. The leak in the main was apparently new. One service leak was left unrepaired in Step D for lack of property owner permission. Another was very small, and the third was on a service line which had been grouted in both Steps B and D.
>
> Section 7 - two services leaking, and one main joint leak. The joint leak in the main had apparently developed recently, perhaps under the increased hydrostatic pressures caused by higher groundwater levels. One service leak was also new, and the second was a service supposedly repaired in Step D. That repair was not effective.

C. STORMS USED FOR COMPARISON OF SYSTEM FLOWS

It is not possible to find two storms which are exactly alike. Thus, one can argue that I/I flows measured before and after rehabilitation were measured under differing conditions and that argument will always be correct. The storms selected for use in comparing I/I flows in the pilot rehabilitation basin are similar, however. Five criteria were used to compare various storms. They are shown on Table 4-4.

D. RESULTS

Figure 4-2 shows the flows from the rehabilitation basin before, during, and after rehabilitation Steps A-E. While the graph shows a general downward trend in system flows as repairs are made, this data is complicated by weather conditions and groundwater levels. In the Skyline Basin, no direct inflow was ever identified. Rather, during and for a few days after each major storm, surface runoff collected in the gravel backfilled sewer trenches, causing large I/I flows in the sewers. As the faults in the sewer system were repaired, the groundwater levels in the sewer trench, as shown in Figure 4-2, rose. The best

Table 4-4

Comparison of Storms and Conditions When Peak Pilot Area I/I Flows Were Measured

Storm	Date	Precipitation During		Groundwater Level at MH 037-740	STP Flows MGD	Bypass	
		Prior 24 Hours in.	Prior 72 Hours in.	in.		@ 650 Idlewood	@ 12th
#1	1-23-82	1.04	1.93	42-1/2	101	NO	YES
#2	12-16-82	0.44	2.42	58-1/2	76.5	YES	YES
#3	2-18-83	0.74	2.64	54-1/2	97.5	YES	NO
#4	2-13-84	1.15	1.64	-	93	YES	NO

STP = Sewage Treatment Plant

1. Measured above shelf of manhole.
2. Measured at 3:00 a.m.

inches x 2.54 = cm
1 hectoliter = 26.4181 gallons

TABLE 4-5
PEAK I/I CONTRIBUTIONS BY PIPE SEGMENT
PEAK I/I CONTRIBUTION - gpd

PIPE SECTION	STEP A INITIAL FLOWS	STEP B REPAIRS	STEP C POST REHAB 1ST TRY	STEP D REPAIRS	STEP E POST REHAB 2ND TRY	STEP F REPAIRS	POST REHAB
1	No Meas.	None	No Meas.	1 Manhole	No Meas.	1 Service	No Meas.
2 & 3	190,802	4 Services 2 Manholes	27,964	10 Joints 1 Manhole (again)	0	None	2,970
4	122,514	9 Services 1 Manhole	1,433	2 Joints 2 Services* (again)	1,860	None	2,920
5	44,429	5 Services	52,187	2 Services* (again)	5,460	None	13,630
6	21,500	4 Services	16,322	1 Joint 1 Service (again)	0	None	0
7	14,500	None	42,000	None	30,240	2 Services	11,290
8	7,265	3 Services 1 Manhole	300	None	300	None	0
9	570	2 Services 1 Manhole	0	None	0	None	0
10	10,000	5 Joints	10,000	4 Shears 1 Hole	5,700	None	3,680
TOTAL	411,060		150,206		43,560		34,490

* - 1 leaking service was not repaired

(1 gal. = 0.0038 cu. m.)

understanding of the actual relationship between the I/I flows and the repairs made is given by Table 4-5. The I/I contributions of various segments of the sewer during three comparable storms are shown. The effect of repairs is more easily seen.

It is interesting to see how flow in pipe sections where incomplete repairs were made sometimes increased when adjacent pipe sections were completely or nearly completely repaired. The best example of hydraulic transfer is seen in section 7, where flows increased dramatically when the downstream segment was repaired. Very likely, this situation also occurred in section 1, but no good flow measurements from that line could be made.

Table 4-6 shows the relationship through Step E between the pipe rehabilitation effort done, and the change in peak I/I flow. "Complete" rehabilitation results in the elimination of most I/I (average I/I reduction of seven sections completely rehabilitated was 97.4%). Rehabilitating just mains and manholes produces more erratic results. In the two sections where only mains and manholes were made watertight, I/I flows decreased 43% in one section and increased 208% in the other. The section with 43% flow reduction is on an easement with no upstream mains connected. Trenches are backfilled with native materials and there is not much opportunity for this line to be effected by "hydraulic transfer." Section 7 clearly shows the effect of "hydraulic transfer." Sewer trenches in that area are gravel backfilled. As downstream repairs were made, water levels in the trench areas were observed to rise. This obviously effected the I/I contributions of section 7.

In all, peak I/I flows within the Skyline Rehabilitation Basin were reduced by about 92%.

E. COSTS

The manpower, materials, and equipment utilized for the Skyline Pilot Rehabilitation Project were recorded. Several tasks such as monitoring groundwater levels, manhole leakage measuring, and measuring sewer service lateral flows were done for this study and would not normally be done as part of a rehabilitation project. Costs of those tasks have not been included in this analysis. Continuous recordings of flows from the rehabilitation basin will be used to determine the effectiveness of rehabilitation work in future efforts, and those costs have been included.

Because service lateral testing and rehabilitation is new, and the techniques, processes and equipment were previously

TABLE 4-6

CITY OF SALEM SKYLINE PILOT REHABILITATION % I/I REDUCTION BY PIPE SECTION

PIPE SECTION	TYPE OF REHABILITATION DONE	THROUGH STEP E % CHANGE IN PEAK I/I FLOWS	THROUGH STEP F % CHANGE IN PEAK I/I FLOWS
2 & 3	Complete	100% reduction	98.4% reduction
4	Complete*	98.5% reduction	97.6% reduction
5	Complete*	87.7% reduction	69.3% reduction
6	Complete	100% reduction	100% reduction
7	Main & manhole (actually no repairs necessary)	208.6% increase	22.1% reduction
8	Complete	96% reduction	100% reduction
9	Complete	100% reduction	100% reduction
10	Main & manhole	43% reduction	63.2% reduction
Composite reduction pending Step F		89.4% reduction	91.6% reduction

"Complete" rehabilitation consists of repairing all faults in mains, manholes, and service laterals.

* One service lateral leak remains

untried, the costs reflected herein are somewhat higher than should be expected for future similar efforts. Too much administrative time was expended in trying to devise workable techniques and equipment. As experience in service lateral rehabilitation work is gained, field technicians will be able to make decisions made by project engineers on the job. Perhaps even more important, techniques and equipment will almost certainly improve. Much improvement in the performance of the snake was realized during the course of the Skyline project.

The costs of the testing and rehabilitation program at Skyline are shown in Table 4-7. Approximately $70,000 was spent eliminating peak I/I flows of 376,500 gpd (1.425 ML/d). The $70,000 includes the cost of repairing a faulty service lateral in section 1. All repairs leave the study area with a peak I/I flow of about 55,000 gpd (0.208 ML/d). Thus, $70,000 has reduced peak I/I flows by about 485,000 gpd (1.836 ML/d).

F. CONCLUSIONS - SKYLINE REHABILITATION PROJECT

1. Where does I/I enter the sewer system?

Most of the main joint leaks were repaired before this study began. Thus, the I/I contributions for joint leaks in mains was quite small. About 8% of the peak I/I flow was contributed by mainline leakage, 91% by service lateral leaks, and less than 1% by manhole leaks.

2. What was learned about service laterals?

Figure 4-8 shows the typical service lateral extension for the Skyline area. At least half of the services inspected were generally as depicted in Figure 4-8. Eighty-eight % of the service lateral pipe was concrete, 12% was PVC. Eighty-seven % of the service laterals needed new cleanouts for air testing and repair work. Thirty-one of 43 service laterals (72%) leaked. Of the service laterals air tested, 90.3% leaked. Of the leaking services, 68% had broken tees or were leaking at or near the first joint out of the main, and 86% had one or more joints leak upstream from the tee. Fifty-four % of the service laterals had bends at or near the property line.

3. How do we repair service laterals?

Four service lateral rehabilitation techniques were used on the Skyline project. These techniques included:

TABLE 4-7
TESTING AND REHABILITATION COSTS
SKYLINE PILOT REHABILITATION

STEP B	Quantity Done	Manhours	Materials	Equipment	Total Cost *	Unit Costs
A. Sewer Mains						
1. TV inspect mains	2084 l.f.	86		43 hrs TV van	$1,227	$0.59/ft
2. Air test joints & grout leaks	396 jts	45	18 gal grout	22.5 hrs TV & grout rig	$ 731	$1.85/jt
B. Manholes						
1. Drill & grout manholes	7 ea	41	341 gal grout	20.5 hrs TV & grout rig	$1,640	$234.40/ea
C. Service Laterals						
1. Research ownerships, prepare notices, contact property owners, get signed property owner agreements	60	161.5			$4,264	$71.07/ea
2. Locate existing cleanouts	32	30			$ 720	$22.50/ea
3. Install new cleanouts	32	267	$730.56 fittings	$648.96 trucks	$5,328	$166.50/ea
4. Air test service laterals	29	55.5		$18.5 TV & grout rig	$2,386	$82.30/ea
5. Clean & TV inspect	28	67		27 hrs minicamera 6.5 hrs cleaner	$3,522	$125.80/ea
6. Air test & grout tees & wyes	test 27 grout 18	70		35 hrs TV & grout rig & cleaner	$5,534	$307.44/ea
7. Snake repairs	765 l.f.	96	104 gal grout	62 hrs snake	$6,863	$8.97/ft
8. Digups, physical repairs & replacements	3			Backhoe, etc.	$1,560	$520/ea
9. Grout services 2-30' up from tee	4	22.5	193 gal	TV & grout rig	$3,408	$852/ea
STEP D						
1. Retest and grout mains	2079	128		grout rig	$7,040	
2. Repair services	5			mini TV, snake	$3,834	

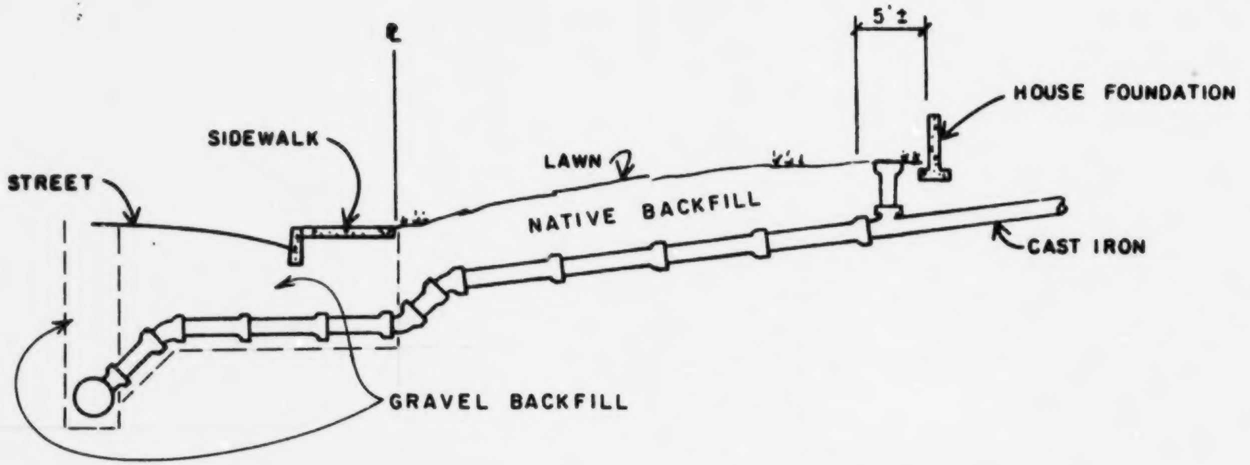
TABLE 4-7 CONT'D.
TESTING AND REHABILITATION COSTS
SKYLINE PILOT REHABILITATION

STEP F	Quantity Done	Manhours	Materials	Equipment	Total Cost *	Unit Costs
1. Install cleanouts	3	34		backhoe	$ 600	$200/ea
2. TV and grout services	3			mini TV, snake	$1,680	$560/ea
3. Test and grout tees	3	16		grout rig	$ 880	$293/ea
GENERAL ADMINISTRATION						
1. Project organization		Eng 91.5 Tech 21.5 Sec 17.0			$6,592	
2. Project implementation, trouble shooting, inspection		Eng 50 Tech 300 Sec 15			$12,230	
TOTAL					$70,043	

* Costs based on:

Hydrocleaner	$85/hr
Mini-camera	$110/hr
TV & grouting rig	$100/hr w/2 man crew
Snake	$100/hr
Grout	$6/gal

(1 Ft = .304801 Meters)


℄
5'±
HOUSE FOUNDATION
SIDEWALK
LAWN
STREET
NATIVE BACKFILL
CAST IRON
GRAVEL BACKFILL

TYPICAL HOUSE SAN. SEWER SERVICE

FIGURE 4-8

A. Plugging the service lateral adjacent to the tee and grouting the tee and one or two joints upstream from the main, Method A.

B. Filling portions of the service lateral piping completely with grout, and then cleaning the excess grout out of the pipe, Method B.

C. Use of the snake.

D. Replacing all or part of the pipe.

No single rehabilitation technique was applicable for all situations. Repair Method A for repairing broken tees and joints near the main worked well in 18 out of 19 cases. Method B worked reasonably well where access to the service lateral piping could not be gained with the snake, although several such repairs failed. This method is most applicable where pipe repairs are close to the main. The amount of grout used is proportional to the length of service pipe filled with grout. With the high cost of grout, repairs are expensive if repairs are made more than 10 to 15 feet (3.05 meters - 4.57 meters) from the main. Method C was a good technique for repairing relatively new service lateral piping. Performance of this equipment has already improved, and further improvements are expected as experience is gained.

Replacing service lateral piping, method D, is an excellent way to make repairs if a pipe is old or dilapidated. In many places, replacement of all or even portions of the service lateral piping is the least acceptable of the repair options available. Excavations can be disruptive, difficult and simply not well accepted by property owners. Some pipe replacements involve digging up patios, paved areas, or landscaped areas, and this adds tremendously to the cost. In the Skyline area, replacement in each instance would be much more expensive than the other repair methods used.

4. What is the effect of repairing service laterals only?

Step B repairs in sections 2, 3, 4, 5, 6, 8 and 9 consisted almost entirely of service lateral and manhole rehabilitation. As the manholes did not contribute significant I/I flows, the I/I reductions measured in step C were primarily from service lateral repairs. Those reductions were:

PIPE SECTION	% PEAK I/I ELIMINATED BY SERVICE LATERAL REPAIR
2 and 3	85.3%
4	98.8%*
5	87.7%*
6	24.1%*
8	95.5%
9	100.0%

*Some service lateral leaks still existed.

Thus, we conclude that service lateral repair by itself is effective only if there are few mainline faults. Conversely, if there is extensive mainline leakage, repairing service laterals by themselves is not very effective.

5. How effective is "complete" rehabilitation which consists of repairing mains, manholes, and service laterals?

From Table 4-6 "complete" rehabilitation is close to 100% effective in reducing I/I flows - as long as hydraulic transfer to other faulty pipes is prevented.

6. How cost effective was each step of the rehabilitation effort?

Judging from the very high I/I flows found in the Skyline Basin at the beginning of this project, the earlier mainline grouting work probably did not reduce I/I flows much. Table 4-8 shows the apparent cost effectiveness of each rehabilitation step, including the grouting done before 1981. Rehabilitation Step D appears to be more cost-effective than Step B, but Step F was less cost-effective than Step D. In the Skyline area, rehabilitation apparently becomes more cost effective as it approaches "complete", but Step F was not very cost-effective because the repairs themselves were not satisfactory.

7. Hydraulic transfer does exist. To eliminate some I/I sources in a system causes other I/I sources to flow more heavily. Thus, where mains are being grouted, relined, or even replaced, manholes and service laterals should be systematically tested and repaired.

8. I/I control requires persistence. Several times during this project, rehabilitation work was done which was expected to completely stop I/I from entering some

segment of the basin. By measuring peak I/I flows later and by making various inspections, earlier repairs (grouted joints, grouted manholes, and grouted service laterals) were found to have failed or faults found which had been overlooked. Rehabilitation must include re-evaluation and reassessment after initial repairs are made.

SUMMARY

This pilot rehabilitation study revealed and documented the importance of service lateral I/I contributions and service lateral repair. It also demonstrated that a very high level of I/I reduction can be achieved through "complete" rehabilitation, and that "complete" rehabilitation may not be excessively expensive.

This small sewer basin is perhaps somewhat unique. The results from this pilot rehabilitation study should not be applied carte blanche to other systems. More documented rehabilitation programs need to be done on other sewer systems so that the results can be compared. We must find out what types of sewer rehabilitation programs work and what the actual costs and effectivenesses are.

TABLE 4-8

COST EFFECTIVENESS OF REHABILITATION STEPS

REHABILITATION STEP	COST	PEAK I/I FLOW REDUCTION ACHIEVED-GPD	COST PER MGD I/I ELIMINATION PEAK FLOW
Main grouting work prior to this study	$15,500*	50,000*	$310,000
Step B Repairs 27 service laterals 5 manholes 5 main joints	$51,526	260,854	$197,528
Step D Repairs 5 service laterals (again) 1 manholes (again) 18 joints and shears	$14,347	106,646	$134,529
Step F Repairs 3 service laterals	$4,169	9,070	$459,647

*Estimated

SECTION 5

MISSOURI REHABILITATION PROJECT

A DESCRIPTION OF BASIN:

In 1981 the Missouri Basin was also established as an area for sewer rehabilitation. This area was chosen because:

1. Flows could be relatively easily monitored.
2. I/I flows were known to be very large resulting in downstream bypasses and overflows.
3. The sewers were typical of mortar jointed concrete sewer pipe installations built before 1958 in much of Salem.

The Missouri Basin is shown on Figure 5-1. The sewers all drain to the 10 in. (25.4 centimeters) line on Missouri Avenue. As shown, the ground slopes from 3% to over 20%. Soils are red silt-clay of volcanic origin which are quite impermeable. All streets are paved and most have curbs and piped storm drainage systems. The basin covers 80 acres (32.37 Hectares), most of which are developed.

All buildings within the Missouri Basin are residences, mostly single family homes. Their ages vary from new to about 30 years. Most homes east of Felton Street are over 20 years old, although some relatively new homes are located in this area. West of Felton, most homes are newer and more expensive. Many of these homes have daylight basements.

The Missouri Basin is served by 13,345 ft (4,067 meters) of sewer main. Most pipe is mortar jointed concrete pipe installed in 1955 and 1956. Only 725 ft (221 meters) of sewer main are known to be rubber jointed concrete pipe. All but 490 ft (149 meters) of main are 6 in. (15.24 centimeters) and 8 in. (20.32 centimeters) pipe. Most sewers are laid under paved streets, but approximately 2700 ft (823 meters) of main lies on easements, usually behind homes to serve uphill houses. Many mains had been grouted prior to 1981.

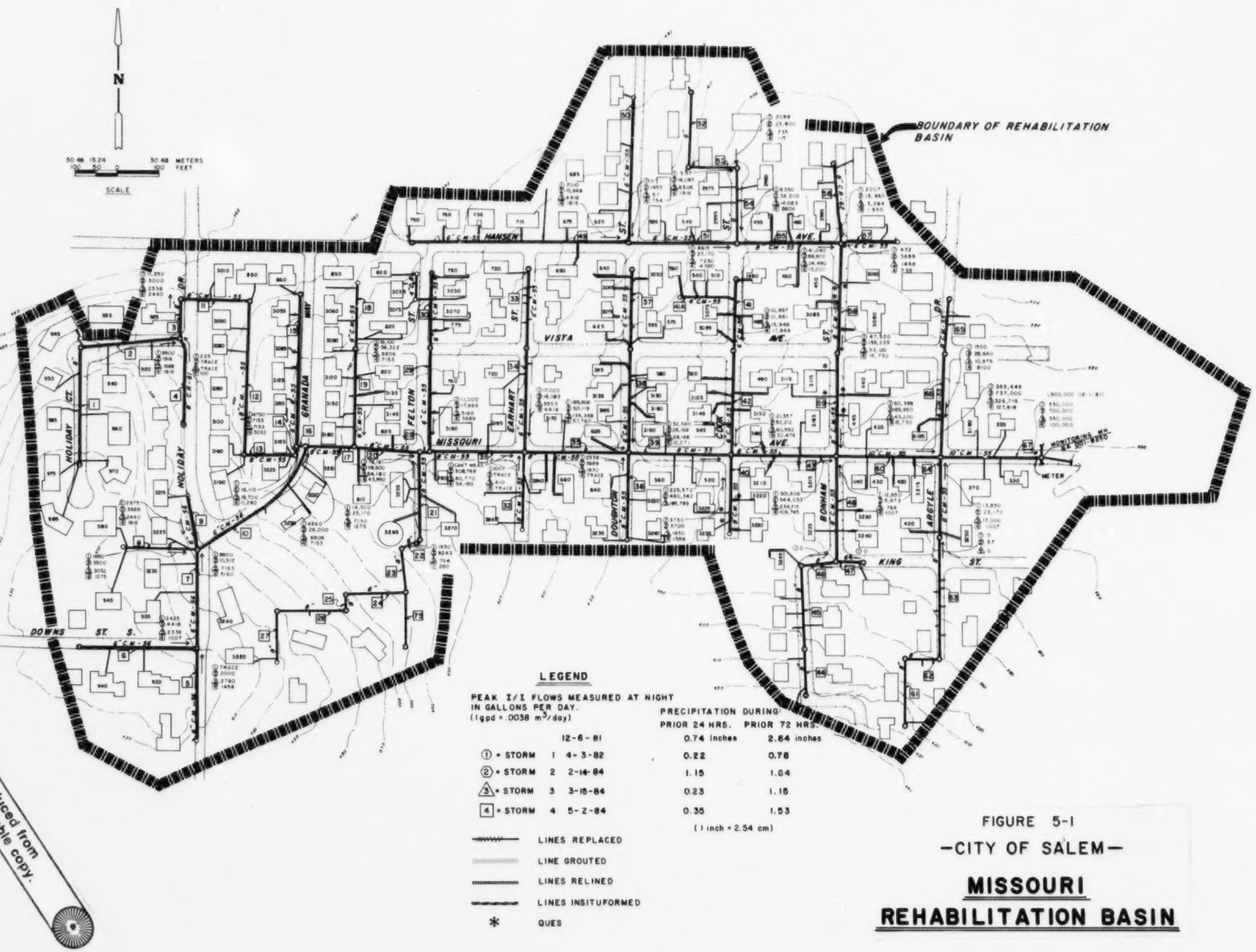

N
30.48 15.24 30.48 METERS
100 50 100 FEET
SCALE
BOUNDARY OF REHABILITATION BASIN
HANSEN
ST.
AVE.
DR.
VISTA
WAY
GRANADA
FELTON
EARHART
MISSOURI
DOUGHTON
COOK
BONHAM
ARGYLE
KING
ST.
HOLIDAY
CT.
DOWNS
ST.
METER
MONITORING
LEGEND
PEAK I/I FLOWS MEASURED AT NIGHT
IN GALLONS PER DAY.
(1gpd = .0038 m³/day)
PRECIPITATION DURING
PRIOR 24 HRS. PRIOR 72 HRS.
12-6-81 0.74 inches 2.64 inches
① = STORM 1 4-3-82 0.22 0.78
② = STORM 2 2-14-84 1.15 1.04
③ = STORM 3 3-15-84 0.23 1.16
④ = STORM 4 5-2-84 0.35 1.53
(1 inch = 2.54 cm)
LINES REPLACED
LINE GROUTED
LINES RELINED
LINES INSITUFORMED
* QUES

FIGURE 5-1

—CITY OF SALEM—

MISSOURI

REHABILITATION BASIN

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B. REHABILITATION PROCESS

The Missouri Basin Rehabilitation Project was initiated in 1982 just after the Skyline Project was started. Information about the existing Missouri Basin sewers was collected between February and May 1982. The data collection was a joint effort of Westech and City of Salem personnel.

In May 1981, work was temporarily stopped for lack of funds. In 1982, City pipe grouting crews grouted joints in mainline piping in sections 1, 2, 3, 5, 6, 7, 9, 10, 11, 13, 15 and 16. This work was done not so much as a part of the sewer rehabilitation study, as to reduce I/I flows. In September 1983 with the help of EPA funding, the rehabilitation project was reactivated.

The Missouri Basin Rehabilitation project since its conception has been a cooperative effort. In 1981 and 1982, the data collection work done was generally under the direction of Westech Engineering, but City of Salem personnel did much of the work. Beginning in September 1983, completion of the rehabilitation work was placed under the direction of Westech Engineering. Westech's responsibilites included organizing and directing all work, obtaining property owner permission for service lateral repairs on private property, maintaining project records, and preparing interim and final reports. Working for Westech as a subcontractor, Gelco Grouting Service was responsible for testing and repairing service laterals. City of Salem personnel continued to maintain and operate the flow monitoring equipment, do all mainline TV inspection work, do manhole and mainline grouting work, and make main and manhole replacements and repairs where excavation and backfill were required.

The Missouri rehabilitation project was conducted in a six-step process. Each step involved a number of tasks. Table 5-1 shows the steps, tasks, and who did the work.

Step A - Initial Conditions

Flow Monitoring--

The Missouri Basin was not firmly established as a rehabilitation area until February of 1982, and consequently, a depth x velocity Flow Monitor was not installed in manhole 01-9300 until around February 20th. Initial measurements made in the Missouri basin earlier in the winter during and after major storms indicated that peak wet-weather flows from the Missouri area can be very high. Instantaneous flows of 1.6 MGD (6.056 ML/d) were measured at manhole 01-9350 on December 6th, 1981.

TABLE 5-1
MISSOURI BASIN REHABILITATION ACTIVITIES

	TASK DONE BY
STEP A - DETERMINE INITIAL CONDITIONS	
1. Continuously monitor basin flows	City
2. Flow map	Westech
3. Monitor groundwater levels	City
4. Map mains and service laterals	Westech
5. TV inspect all mains	City
6. Measure manhole leakage	Westech
7. Collect and tabulate sewer information	Westech
STEP B - PHASE 1 REHABILITATION	
1. Organize and direct work	Westech
2. Repair mains	City
a. Clean mains	City
b. Air test and grout joints	City
c. Grout dead tees	City
d. Air test and grout live tees	City
e. Dig up and repair broken pipes, service risers	City
f. TV inspect	City
3. Repair manholes	City
4. Repair service laterals	
a. Obtain property owner authorization	Westech
b. Locate and map service laterals	Westech
c. Install cleanouts	Gelco
d. TV inspect service laterals	Gelco
e. Air test service lateral	Gelco
f. Repair or replace service laterals	Gelco
STEP C - MEASURE POST REHABILITATION CONDITIONS	
1. Flow map	Westech
2. TV inspect selected sewers	City
3. Retest service laterals as appropriate	Gelco
4. Re-evaluate and determine additional repairs needed	Westech

STEP D - PHASE 2 REHABILITATION	
1. Organize and direct work	Westech
2. Repair mains	City
3. Repair manholes	City
4. Repair service laterals	Gelco
STEP E - MEASURE POST REHABILITATION CONDITIONS	
1. Flow map	Westech
2. TV inspect mains - selected	City
STEP F - TABULATE INFORMATION AND PREPARE REPORT	Westech

The flow meter was maintained in manhole 01-9250 during the 1982-83 and 1983-84 winters.

Groundwater Level Measurements--

Four groundwater level monitoring stations were established in 1982, one in the sewer trench, and one nearby in native soils at manholes 01-9350 and 01-9550. These monitors were measured and recorded periodically during the rehabilitation process.

Smoke Tests--

All sewers were smoke tested by City crews during September 1981. The smoke tests indicated seven service lateral leakage problems and several apparent interconnections between storm drainage piping and the sewer system. Smoke was found eminating from five stormwater catch basins. It was later determined that none of the catch basins were directly connected to the sanitary sewers. Rather, open jointed storm sewers near leaking sanitary sewers resulted in water running from the storm sewers into sanitary sewers.

TV Inspections--

Most mains were TV inspected between 1973 and 1979. In 1982, most mains were inspected again. The 1982 reports revealed:

a. 33 leaking service laterals

b. 129 visibly leaking main joints

c. 26 holes in main

d. 101 broken pipes or shears

e. 46 root intrusions

It is interesting to note that although many of the sewer mains were previously grouted, there were numerous visible joint leaks in previously grouted pipe.

Wet-Weather Flow Measurements--

In the early morning hours of April 3rd, a series of instantaneous flow measurements were made throughout the Missouri Basin. Those flows are shown on Figure 5-1. Those measurements were made near the end of a moderately wet period, and system flows were fairly high. This rainy period was not nearly as severe as were other rainy periods earlier in the winter of 1981-82, but indicated which sewer sections were the primary I/I contributors.

Step B - Phase 1 Rehabilitation Work

Mainline Repairs--

City crews were responsible for all main repairs. By February 15, 1984, 43 of the 68 pipe sections in the basin had been grouted. This includes the grouting work done in 1982 and includes virtually all mains originally scheduled for grouting.

All grouting utilized acrylamide chemical grouts and most grout included 3-5% Celite by weight. Joints were air tested at 5-6 psi (3.44 - 4.14 Newtons per square centimeter). On four sections of rubber ring jointed concrete pipe, four of 225 joints failed an air test (1.8%) and required grouting. On the mortar jointed concrete pipe, 1,453 of 2,976 joints required grouting (48.8%).

As main grouting was done in fall 1983 and early 1984, abandoned tees and service laterals were plugged with grout by positioning the packer over the opening in the tee or wye, and pumping several gallons of grout into the opening. Also, where service laterals were being tested and/or repaired, the main tees and the first 2 to 5 ft (.60 - 1.52 meters)of service lateral pipe upstream were air tested and, if appropriate, repaired by grouting. This was done with the same techniques used in the Skyline Project (see page 9).

City crews also dug up and replaced numerous broken pipes, cracked pipes, broken tees and protruding taps. These faults were identified from earlier TV inspections and by reviewing video tapes. Excavation and repair was utilized where chemical grouting did not appear advisable.

Manhole Repairs--

City crews repaired manholes. Many were repaired by drilling and chemically grouting. Others were repaired using quick setting cements, or frames were reset, etc.

Service Lateral Testing and Repair--

Before starting Step B, faulty service laterals were known to be significant I/I contributors on about 20 sewer main sections. In these areas, the systematic testing and, if necessary, repairing of all service laterals was planned. The work plan was devised so methods of accessing service laterals, methods of repairing service laterals and the effectiveness of:

a) repairing mains and manholes only;

b) repairing mains, manholes and service laterals to 8 ft (2.44 meters) from the main;

c) repairing mains, manholes and service laterals to the property line;

d) repairing mains, manholes and service laterals to the house.

could be evaluated.

In concept, all service laterals connected to the same section of main would be accessed, tested and repaired in the same way. Then, after the main was made watertight, all wet weather I/I measured would be contributed by service laterals, thereby indicating the effectiveness of the service lateral rehabilitation work done. Unfortunately, the analysis did not yield conclusive results because of difficulties in adequately repairing sewer mains. Unless mains were known to be watertight upon completion of Step B, there was no way to accurately measure the service lateral I/I contribution for each segment of main. Sealing these 30 year old mains proved more difficult than anticipated.

Service lateral repair work was done as follows:

First, wherever service lateral repairs on private property were to be made, authorization from the property owners was obtained. In all but a few cases, these authorizations were secured by contacting the property owners, explaining what was to be done, and asking for their authorization. As this work was being done as a City experiment, the City bore all costs. All property owners except for perhaps six or seven, were cooperative and pleasant. Many were happy to see their service laterals repaired and several indicated that they had had problems with their service piping in recent years.

After authorization was obtained, the service pipe was located and access to the service lateral was gained by one of the following methods:

Access Methods

A. By installing a cleanout, usually adjacent to the building.

B. By digging the pipeline up, usually adjacent to the property line, but sometimes just inside the curb.

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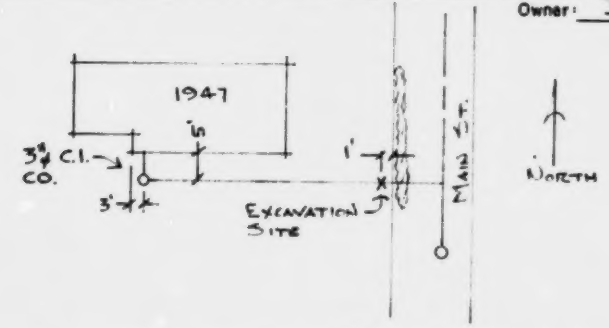
PROJECT: Missouri
Basin:
Line: N° 64
Service To: 1947 Main St.

WESTECH ENGINEERING, INC.
3421 - 25th Street S.E.
SALEM, OREGON 97302
Phone 585-2474

Owner: Jane Doe



Sketch

Air Test Results **Public**	**Private**
0 - 10 Fail	0 - 10 Fail
10 - 20 Fail	10 - 20 Pass
20 - 24 Fail	20 - 55 Fail
0 - 24 Pass - Retest 4/5/84	

TV Inspections	
0 - Dig Up - Start Run	0 - Dig Up - Start Run
4' - 22° Bend Down	33' - Roots, Light
5' - Trans. To Conc.	58' - Service Tap
8' - 22° Bend Down & Left	59' - 45° Bend - End Run
18' - 22° Bend Down & Left	
24' - 45° Bend Down To Main	

Type Pipe: Orangeburg **Size:** 4 in.	Orangeburg **Size:** 4"
Condition: Fair	Fair - Egg Shaped
Smoke Test:	

REPAIRS: Date 1 /17/1984	**REPAIRS:** Date 1 /18/1984
Grouted From Dig To Main Line	P.E. Lined From C.O. To Excavation
City Tested & Grouted Main Tee	Total Liner Length = 56'-9"
Pushed Plug To 20 FT. From Main	
Pumped Grout Until Pressure Passed	
Grout Around Packer	

FIGURE 5-2
TYPICAL SERVICE LATERAL
INSPECTION & REPAIR REPORT

C. From within the mainline pipe.

Approximately 10% of the service lines had existing cleanouts or access pits which were suitable for the equipment.

The service lateral inspection and testing procedure was as follows:

Testing and Inspection Methods

1. In almost every case a small diameter television camera was pushed through the service line. The inspection was video taped and a report was made. See Figure 5-2.

2. Some service laterals were found to be full of roots, obviously cracked, broken, squashed or otherwise deficient. For these, a decision was made regarding repairs from the TV inspection alone.

3. The rest of the service laterals were air tested using a double ball air test apparatus (see page 77) and leaks in the service lateral piping were identified and located.

Following the TV inspections and air testing, decisions were made regarding the appropriate type of repair or replacement. In many cases, the service lateral was constructed with more than one type of pipe. Often, the piping on private property was different from the piping under the street. Many service laterals had to be repaired by more than one technique. Many services were constructed of Orangeburg pipe, which was often in very poor condition. Orangeburg pipe is an inexpensive fiber pipe used in the Northwest during the 1950's. Sometimes it could be lined using polyethylene pipe, but often had to be replaced. Every service lateral leaked at its connection to the main.

The repair work utilized one or more of the following techniques:

Repair Methods

1. The Cues internal pipeline service lateral packer (see page 81) was used as an experiment to test and repair some services. The use of this equipment was intended to test and repair all 16 service laterals on pipe sections 40, 43, 58, and 59. This effort was complicated by bad weather, badly constructed piping, and high flows in the pipelines. Consequently, twelve service laterals were tested and repairs attempted with this equipment. Six repairs proved satisfactory but the other six had to be repaired later by other means. Several had riser pipes so broken that they

could not be repaired by grouting and others leaked excessively upstream from the initial repairs. The Cues equipment works from within the main and can test and seal a service pipe for a distance of 6 to 8 ft (1.83 - 2.44 meters) up from the main.

2. Structurally sound service lateral piping was grouted using the Westech/Gelco snake (see page 82).

3. Service lateral pipes which were reasonably straight but structurally deficient or full of roots were often lined with polyethylene liners. The 3 1/2 in. (8.89 centimeters) liner pipe was pushed into the 4 in. (10.16 centimeters) service lateral pipe and was connected to existing piping at the upper end with a rubber coupling. At the lower end, the PE liner was either plugged and grouted in place using the mainline packer or the mainline tee was dug up and the liner pipe was coupled to the mainline tee (see page 87).

4. Some service piping was repaired by installing Insituform liners. This work was experimental (see page 92).

5. Some service piping was replaced, that being the cheapest or best repair method in that place.

Table 5-2 itemizes the repairs made in both steps B and D.

As of Feburary 13, 1984 all of the mains scheduled for grouting and all of the services scheduled for Step B repairs were thought to be complete. Wet-weather flows were mapped and large flows were found arising throughout the Missouri Basin. Those flows are shown on Figure 5-1. Particularly disturbing were the large flows coming from sewers where mains, manholes and service laterals had all been repaired. What was wrong?

During the next few days, many sewer lines were TV inspected. Many large mainline leaks, some coming from joints and others from holes in pipes, were found. Numerous service lateral leaks were found also, most from services which had not been repaired or had been repaired only for part of its length.

An accelerated program of retesting and resealing mainline and service lateral leaks was undertaken. Most downstream from Granada Way were retested and resealed during the next month. Eventually most faults were repaired except in lines 17, 19, 41, and 42. Tests and inspections eventually led to the conclusion that those pipes were so poor that grouting could not seal them.

TABLE 5-2

MISSOURI BASIN - REPAIRS MADE

	Repaired Step B	Step D	Total Repaired	Total in Basin
Mains				
Sections grouted	43	4	47	68
l.f. grouted	9413	849	10,262	13,345
Manholes				
Repaired	?			70
Built	1		1	
Tees				
Live tees tested	73	4	77	
Live tees sealed	55	4	59	
Live tees replaced	19	8	27	
				220
Service Laterals				
Installed cleanouts	49	5	54	
TV inspected	75	11	86	
Air tested	70	8	78	
Repaired				
by Cues unit	7	0	7	
by Snake	25	2	27	
by PE liner	15	5	20	
by Insituform	5	1	6	
Replaced	20	2	22	

(1 ft x 0.304801 = meters)

After joints were sealed, TV inspections revealed large flows running thru the pipe walls.

Step C - Post-Rehabilitation Conditions

By March 15, 1984 the Step B repairs were complete. Again, flow mapping and wet weather TV inspections were completed. The flows measured are shown on Figure 5-1. A list of Step D repairs was prepared which included main line repairs on 13 sections of main which had been previously grouted, about a dozen manhole repairs, and 20 service lateral repairs, eight of which had not previously been repaired and 12 of which either were still leaking or needed to be repaired upstream of earlier repairs.

Step D - Phase 2 Repairs

This work was done just as the Step B work was done. Most of the Step D repair work was completed by May 2. The replacement of lines 42 and 43 have not yet been completed, nor have lines 17 or 19 been replaced or lined (ca 1984).

C. RESULTS

1982 wet-weather flow monitoring records show peak wet-weather flows from the Missouri Basin of over one MGD (3.785 ML/d) and on one instance a 1.6 MGD (6.056 ML/d) flow was measured. The highest 83-84 flow measured was over one MGD (3.785 ML/d) occurring on Feburary 13, 1984 just as the Step B repairs were thought to have been completed. Between February 13 and March 15, many sewer mains were again tested and grouted and some service laterals were retested and repaired again also.

The highest flow after the Step B repairs were completed on March 15, 1984 was recorded on April 10, 1984. That storm was somewhat less severe than the earlier storm on February 13. Between March 15 and April 4, Step D repairs were made. Those repairs included a number of faults which obviously contributed large I/I quantities to system flows. Figure 5-3 shows our best estimate of the flow reductions achieved through the rehabilitation program. Using flows accurately recorded from other nearby sewer basins during the same storms, estimates of Missouri Basin flows comparable to the 12/6/81 and 2/13/84 storms have been made. This analysis indicates that approximately 76% of the system I/I flow has been removed by the rehabilitation work completed. Flows monitored during the 1984-85 winter will complete this analysis.

After the Step D repairs were completed, flows were again measured during a stormy period on May 2, 1984. Approximately

40% of the I/I flow remaining was entering sections 17, 19, 41 and 42. These are the pipelines which had been grouted and regrouted several times. Close inspection revealed porous piping which cannot be repaired by grouting. Lines 41 and 42 will be replaced during Fall 1984.

As explained earlier, the effectiveness analysis of repairing none, some or all of each faulty service lateral was not very conclusive. The difficulties experienced in making the mains watertight prevented meaningful pre-rehabilitation and post-rehabilitation I/I comparisons.

Figure 5-4 shows data collected upon completion of Step B; the Phase 1 repairs. Results from lines where significant faults in mains or repaired service laterals were later found are not included. The information shown is an indication, but certainly less than a scientifically accurate evaluation of rehabilitation effectiveness. Generally, the most extensive service lateral rehabilitation work was done in wet areas with large I/I contributions; less extensive rehabilitation was done in drier areas. This may have skewed results.

For instance, on lines 1, 2, 3 and 4, all concrete rubber ring jointed pipe, only relatively small I/I contributions were ever found. No significant service lateral I/I contributions were found. Thus, when a few faulty main joints were repaired, a large percentage of I/I was eliminated. In a wet area with many service lateral faults, repairing the main only would certainly result in much smaller I/I reductions.

Some observations about the relationship between effectiveness in reducing I/I and the extent of service lateral repairs made are worth mentioning:

1) The water resulting in large I/I flows entering service laterals does not often originate in the ground along the service lateral itself. Rather, as repairs are made to mains and manholes, water tends to pond along the main. If service lateral faults exist at an elevation below the ponded water level, large flows can enter. In several cases, service laterals, where little or no I/I entered before rehabilitation started, were found gushing huge flows into the main after the main had been sealed.

2) Topography is an important factor. Some service lateral piping is in locations and at depths where little or no groundwater or stormwater can enter. For instance, the services connected to line 15 all serve

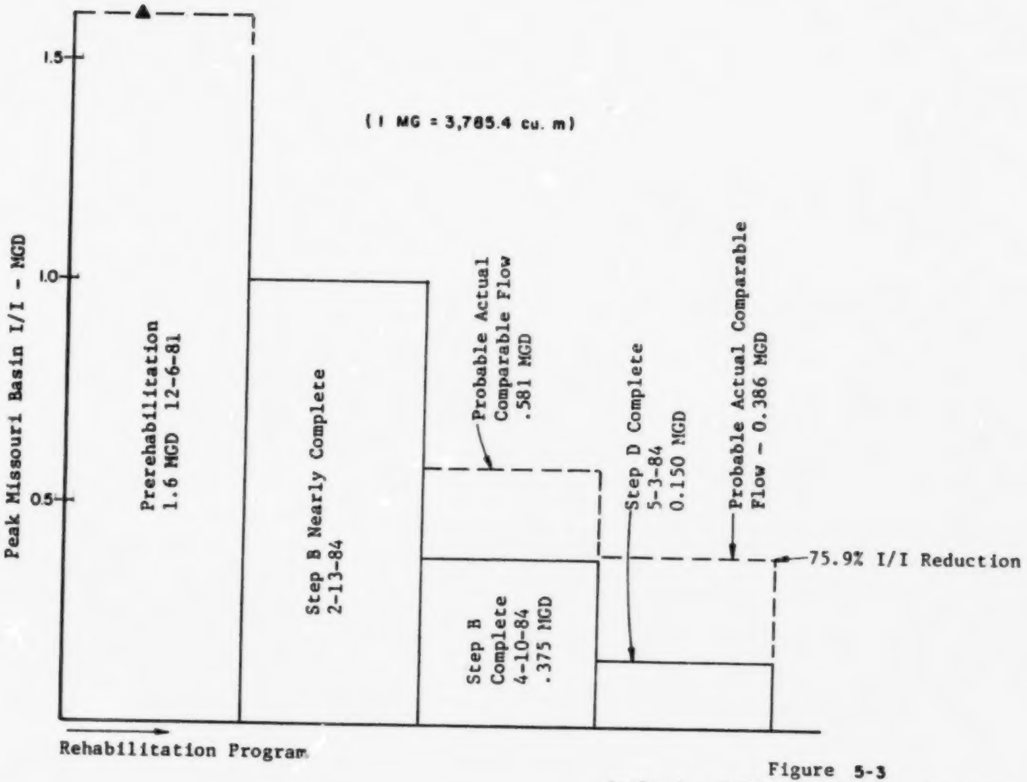
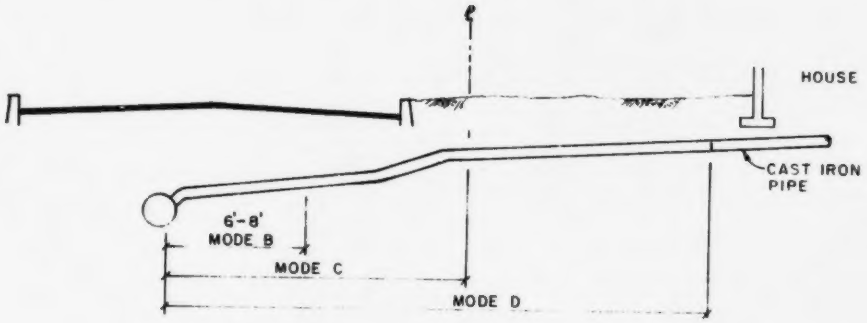


Figure 5-3
Analysis of Missouri Basin I/I Flows

FIGURE 5-4

EFFECTIVENESS OF COMPARATIVE REHABILITATION



Repair Mains & Manholes Only		Repair Mains, MH's 6-8' of Service		Repair Mains, MH's & Services to Property Line		Repair Mains, MH's & Services to House	
Lines	Reduction (%)	Lines	Reduction (%)	Lines	Reduction (%)	Lines	Reduction (%)
1,2	83	40	58	30	64	48	94
3	24	58	3	43	100	55	87
4	80	59	22	60	100		
5	0						
6	0						
7	68						
9	18						
11,12,13	0						
33	61						
34	72						
Average Reduction:	37.6		27.7		88		90.5

NOTE: Because of difficulties in sealing mains, the information presented in this table is not considered highly reliable. Only sewer sections where no mainline faults were subsequently discovered were used for this analysis.

(1 ft x 0.304801 = meters)

homes uphill from the sewer main. The service laterals are shallow and all slope steeply to the main. Here repairing service laterals from the main to 8 ft (2.44 meters) up the service lateral eliminates almost all opportunity for I/I to enter the pipe. Where the ground is flatter, ground water levels higher or sewers deeper, repairing just the lower 6 to 8 ft (1.83 - 2.44 meters) of service of lateral pipe may not remove much I/I at all.

3) The portion of the service lateral pipe near the main, particularly where beneath the street, is especially critical. Here the pipe is usually deepest, the gravel backfills tend to collect and transmit water, and the service lateral piping has the most opportunity to collect large flows. It is also an area where faulty piping frequently is found.

D. COSTS

A good record of project costs incurred after October 1983 is available. Costs incurred before that date are estimates. Table 5-3 shows known costs and estimates of the other costs involved in this rehabilitation project. Some costs are undoubtedly higher than they would be if the project were to be done again. For instance, the involvement of management from three different groups - Westech, the City, and Gelco Grouting Service not only expended a large amount of supervisory time, but the close coordination between the decision making personnel and project workers which is necessary to accomplish the repair work efficiently, was not always possible.

Additionally, some of the efforts and tasks undertaken were done so that a scientific evaluation of the project could be made. Much work done, particularly some techniques and equipment utilized in service lateral testing and repair was new, semi-experimental, and the people involved were not thoroughly familiar with the equipment or techniques. A great deal was learned as the work progressed. Many operations in the latter stages of the project were done more efficiently than done in the earlier stages of the project. Further, some work was done so that special techniques or equipment could be tried, usually at substantially added cost, rather than utilizing preferred and often less expensive equipment or techniques. All of these factors tended to increase project costs.

Conversely, there are several sections of sewer main which were eventually determined to be unsuitble for repair utilizing

TABLE 5-3

MISSOURI BASIN - COSTS

1.	Preliminary work - Westech 1981-82	$5,000 est.
2.	City inspections, smoke testing, flow monitoring - 1981-82	$20,000 est.
3.	City grouting work - 1982	$20,000 est.
4.	City repair work, grouting work October 1983 - March 31, 1984	$84,299
5.	Westech/Gelco October 1983 - June 1984	$184,993

Probable Total Cost Range for Project $300,000 - $375,000 grouting techniques. The pipelines need to be replaced, Insituform lined, or PE lined. In any case, the mainline repairs utilizing these suggested techniques will be more expensive than grouting. The cost of replacing or lining the pipe sections in question is not reflected in Table 5-3.

Gelco did all service lateral repair work at a total cost of $126,375 for 87 services. Thus, the average cost of service lateral testing, inspection and repair was $1,452. Most service lateral work was done on a time and materials basis. A tabulation of costs for various operations is shown in Table 6-5.

E. CONCLUSIONS

1. The Missouri project demonstrated why sewers need to be rehabilitated basin by basin. Reducing I/I in a sewer basin is difficult. Unless pre-rehabilitation flows are monitored and then post-rehabilitation flows are monitored, no one can tell reliably whether I/I flows have been reduced by rehabilitation or not. It was only by post-rehabilitation flow monitoring and subsequent corrections that I/I was reduced significantly.

2. In most sewer systems, it is important to determine which sewer basins should be rehabilitated and what the priorities should be. Wet-weather flow mapping or flow monitoring of I/I flows from suspect sewer basins is one way to determine the relative I/I contribution of various basins. Many other factors may also effect the prioritization of sewer basins for rehabilitation. Generally, the basins where I/I flows are greatest, cause the most problems, restrict community growth, or can be eliminated most easily should be rehabilitated first.

3. Once the sewer basin to be rehabilitated has been selected, monitor pre-rehabilitation flows, flow map during extreme wet-weather conditions to determine which sewers in the basin contribute significant I/I, then inspect and make the necessary repairs to the sewers actually contributing significant amounts of I/I. This procedure was not strictly followed in the Missouri basin, as virtually all sewer lines were TV inspected in 1981, regardless of whether they contributed significant I/I or not. Some lines were TV inspected in 1981 and were later repaired which never have contributed more than very small I/I flows.

4. Sewer rehabilitation is not a one shot process. For instance, as of February 13, 1982 when all of the Step B repairs were thought to have been completed, I/I flows were measured and found to be little changed from the flows originally measured in 1981. This was after repairs had been made to most mains and service laterals which had contributed significant I/I. Only through continued sewer monitoring, wet-weather flow mapping to identify where remaining I/I flows originated, and further repairs was I/I significantly reduced.

5. Sewer rehabilitation needs to be a comprehensive program. Not only do mains need to be repaired, but also faulty manholes and service laterals. As repairs were made to sewer mains in the Missouri basin, dramatic increases in I/I flows entering some service laterals, manholes and faulty pipe joints was noted. The effectiveness in reducing the I/I by making just one type of repair, i.e. just repairing mains or manholes for instance, seems to vary. In some places, lines one and two for instance, repairing the main significantly reduced I/I. Conversely, I/I flows entering line 42 increased by nearly 400% when adjacent sewers on Missouri Avenue were sealed, even though line 42 was grouted.

6. Most Missouri Basin sewers had joints which are not watertight and most service laterals were faulty also, yet it was not necessary to repair all faulty piping in order to substantially reduce flows. Much faulty piping is located where, because of topography and soil conditions, the pipe is never exposed to significant amounts of surface water or groundwater. If a pipe is faulty but is not exposed to groundwater, no I/I enters it. In the past, TV inspection of sewer mains has been used extensively to determine which lines should be repaired. The tendancy has been to repair all sewer mains shown by TV inspections to be faulty, regardless of whether the faulty pipe collects significant I/I or not. Through the flow mapping process during extreme wet-weather, one can determine whether a section of sewer line collects significant I/I or not. In the Missouri Basin, 77% of the mainline pipes were repaired and 37% of the service laterals were tested and repaired. Far less than 100% of the faults need to be repaired to dramatically reduce I/I, but most faults collecting significant I/I must be repaired.

7. An experienced person by observing drainage patterns can predict with reasonable accuracy which sewer lines will

contribute significantly to I/I. Some areas obviously collect groundwater and surface water more readily than others. The areas that collect water and the sewers that run through them, are suspect.

8. Timing is important. Each year there are several opportunities to do flow mapping under ideal conditons. The difference between the information gathered under ideal conditions and under less than ideal conditions is tremendous. One or two missed opportunities during the course of a rehabilitation project can set that project back significantly. Likewise, timing is an important factor in doing the TV inspection work. Twice during the Missouri project, TV inspections of sewer lines were made during and immediately after a rainy period of 2 or more in. (5.08 centimeters) in two or three days. These TV inspections revealed porous pipe, faulty joints, gushing services, large holes in the pipe running large flows of water, etc. TV inspections made just a few days later would reveal little of this information. Repairing manholes during wet weather is important, because a high groundwater level allows the repair crews to know whether the leak is actually being stopped. Service lateral repairs can be done during dry weather.

9. The difference between repairing sewers in the Missouri Basin and repairing sewers in the Skyline Basin is large. It is much more difficult and expensive to repair older mortar joint pipes than newer rubber ring jointed pipes. Much of the piping in the Missouri Basin is brittle, broken, sheared, or has holes in it.

10. A large number of broken pipes, broken tees, smashed service lateral pipes, etc., were repaired in the Missouri Basin by digging up and replacing the pipe. In many cases, the dig up and repair work was not done until after adjacent piping had been grouted. In almost every case where a connection was made to adjacent piping which had been previously grouted, the grouted joints in the adjacent piping were later found leaking. Replacements should be done before adjacent grouting work is done.

11. Sewer rehabilitation work is challenging, difficult, demanding and sometimes unpleasant. Working in sewers under the best of circumstances, is not a prestige job. Unless the people involved are really interested in reducing I/I flows, rehabilitation results will probably be disappointing. Strong incentives are needed to get field

people to do the testing, flow mapping and repair work, often under adverse conditons, so that good results are obtained.

12. Quality control is extemely important. The difference between successfully sealing all faulty joints in a sewer and sealing 95% of the faulty sewer joints can be huge. In the Missouri Basin, many sewers collected virtually the same I/I after initially grouted as before grouting. Subsequently a few joints or holes were found still leaking. When those faults were repaired, flows decreased dramatically. Quality workmanship is also needed for manhole repairs, service lateral repairs, flow mapping and other aspects of sewer rehabilitation.

13. The last few repairs in a small basin can result in dramatic flow reductions. For instance, flows from the sewers upstream from Section 59 were measured on February 13, 1982 at nearly 200,000 gpd (0.757 ML/d). Inspections and tests revealed several leaking joints, seven badly leaking services, and a couple of manhole leaks. Repairs were made and on May 2nd, the total flow from these lines measured just 16,000 gpd (0.060 ML/d), almost all of which was coming from a short line which had not been repaired. After Step B repairs were nearly complete, flow mapping revealed a single faulty joint in line 28 contributing nearly 100,000 gpd (0.378 ML/d). When that single joint was repaired, not only did I/I drop dramatically, but the groundwater level in that area rose substantially, and the adjacent manhole began leaking profusely at the top of its first riser.

14. Sewer rehabilitation organization and administration is very important. To be effective, there must be very close communication between decision makers and field personnel. There must be close coordination and cooperation between the workers on service laterals, on dig up and repair work, on manhole repair work, and on mainline grouting. The process needs to be carefully orchestrated.

15. Some sewers in the Missouri Basin are not suitable for repair by grouting. Unfortunately, that information did not become apparent until after several attempts at grouting them had been made. Then, only by TV inspecting the pipelines under wet-weather conditions and viewing water running through the pipe walls, did the futility of grouting that pipe become apparent. Some method for identifying sewers which cannot be successfully grouted needs to be established. The Missouri Basin sewers with porous walls

were concrete pipe with very rough interior walls and the aggregate was exposed. Some sewers had numerous shears and holes. TV inspection crews should watch for and identify these conditions. When TV inspections reveal sewers with many shears, breaks or rough interiors, the video tapes should be carefully reviewed before a decision is made of how to repair the pipe.

SECTION 6

SERVICE LATERAL TESTING, INSPECTION AND REHABILITATION

A. LOCATING FAULTY SERVICE LATERALS

We need to determine as expeditiously and inexpensively as possible which service laterals contribute significant I/I. Unfortunately, there presently is no procedure or equipment which locates all leaking service laterals quickly, easily and cheaply.

Methods presently used to locate leaking service laterals are:

1. Smoke Testing

Smoke testing consists of blowing non-toxic smoke into sewer lines, usually through manholes and then looking for smoke eminating from faulty sewer installations. Typically, smoke testing will reveal connections with storm drainage facilities, connections to roof drains, major pipe breaks, etc. Smoke testing is relatively inexpensive, often costing only about $0.15 per foot of sewer main tested. It does not, however, reveal most service lateral faults. In the Skyline area, only one of 31 faulty services were discovered by smoke testing. In the Missouri basin where probably over 90% of all 220 service laterals are faulty, smoke testing revealed only seven service lateral leaks. Further, service lateral faults identified by smoke testing aren't necessarily the faults which collect much I/I.

2. TV Inspections of Mains

TV inspecting sewer mains is sometimes a good way to identify faulty service laterals. Inspections must be made during relatively wet-weather so that flows entering the main from the service lateral can be viewed. Care must be taken to determine which flows are I/I and which are sanitary sewage. This is done by positioning the TV camera in the main just upstream from the service tee. The service lateral flow is viewed for several minutes to see if it varies in volume, steams or has solids or color in it. All indicate that the flow is sewage rather than I/I. TV inspecting mains usually costs less than $1.00 per foot. If done when groundwater levels are high, TV inspecting can be an inexpensive way to identify most I/I contributing service laterals. Most faulty service laterals in the Skyline area were identified by T.V. inspections of mains. Many faulty services in the Missouri basin were identified that way also. It is usually a mistake to repair only service laterals producing large I/I flows, because as other repairs are made, typically laterals initially producing small flows begin contributing large flows. Often service laterals are not found contributing I/I until after other system repairs are made and groundwater levels rise. Thus, the initial TV inspections may not reliably identify all faulty service laterals which must be repaired. If wet-weather flow mapping is done first to identify the sewers not contributing significant I/I, only the remaining mains need to be TV inspected.

3. Systematic Approaches

All other methods for discovering faulty or leaking service laterals involve systematically testing or inspecting each service lateral. There are several procedures now used for systematically testing service laterals to find the faulty ones. They are:

a) An air test from cleanout at the building to the main, as done on the Skyline project.

b) Air test just the tee at the main and two to five ft of service lateral upstream, as done on the Skyline Project.

c) Air test using a double ball air test apparatus. See Figure 6-3 and page 70. This was used in the Missouri Basin.

d) Air test the tee and six to eight ft (1.83 meters to 2.44 meters) upstream using the Cues Lateral Sealing System.

e) TV inspect service laterals.

f) Hydrostatic tests.

Summary

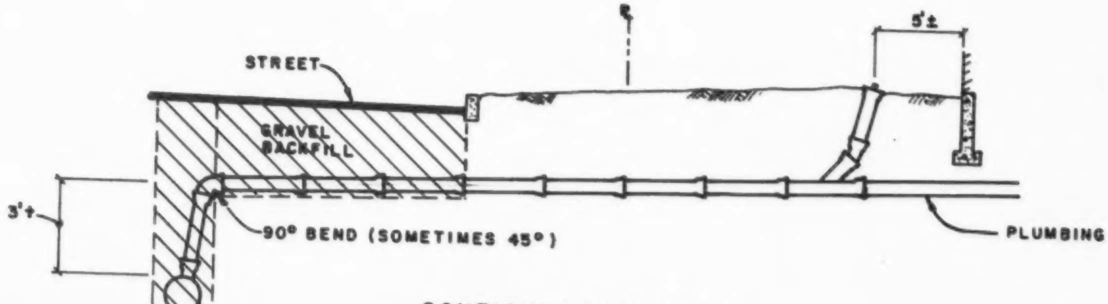
There is no ideal method to determine which service laterals are faulty and contribute significant I/I. Smoke testing is inexpensive, but reveals only a small percentage of the faulty services. TV inspecting mains, if done during wet weather, will reveal most faulty service laterals which are major I/I contributors. TV inspections are especially appropriate for systems where only relatively few service laterals are significant I/I contributors. The systematic testing approaches are most applicable in older systems where most service laterals are faulty. Systematic testing is expensive.

B. TYPICAL CONFIGURATIONS AND CONDITIONS

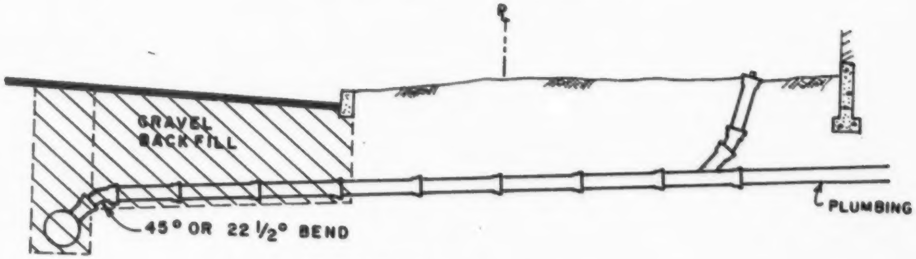
Figure 6-1 shows some typical service lateral configurations, and the manner in which the sewer main connection is made. In the Skyline Basin, most service laterals were constructed per configuration #2 or configuration #3. In the Missouri Basin, many services were constructed per configuration #1. Configuration #1 is particularly troublesome because the riser from the main seldom is properly supported, and many installations were broken and shattered beyond repair.

Most Skyline service laterals had cleanouts adjacent to the homes. Many of these cleanouts were difficult to locate, and virtually all when found, would not allow access of equipment to test, inspect and repair the laterals. Many were constructed with 4 in. (10.16 centimeters) tees. Getting TV cameras and other such equipment thru a tee at the bottom of a cleanout is difficult or impossible. Many service laterals were built with 3 in. (7.62 centimeters), rather than 4 in. (10.16 centimters) diameter risers or had 3 in. (7.62 centimeters) cleanout caps. All but four existing cleanouts in the Skyline area had to be replaced before the testing and repair program could proceed. Similar installations were found in the Missouri basin.

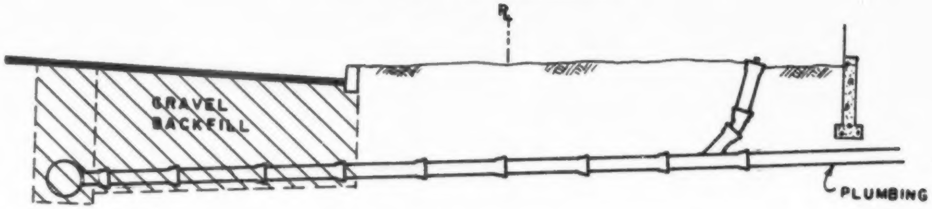
In the Skyline Basin, all service lateral piping was constructed of 4 in. (10.16 centimeters) rubber gasket concrete pipe, or 4 in. (10.16 centimters) diameter PVC pipe. All pipes were reasonably well constructed and appeared to be structurally sound. In the Missouri basin, all service laterals were also 4 in. (10.16 centimeters) diameter, but were constructed of mortar jointed concrete pipe, cast-iron soil pipe, PVC pipe, and asbestos cement type. Some service laterals were structurally sound; many were not. Much Orangeburg pipe and some of the concrete pipes were eggshaped. Many service lateral pipes had significant root intrusions. In many places, the pipes used in the street right-of-way and on private property were different. Table 6-1 lists the configurations, materials and types of faults discovered in these two areas.


STREET
℄
5'±
GRAVEL BACKFILL
3'±
90° BEND (SOMETIMES 45°)
PLUMBING

CONFIGURATION No. 1


℄
GRAVEL BACKFILL
45° OR 22 1/2° BEND
PLUMBING

CONFIGURATION No. 2


℄
GRAVEL BACKFILL
PLUMBING

CONFIGURATION No. 3

FIGURE 6-1

TYPICAL SERVICE LATERAL CONFIGURATIONS

TABLE 6-1

SERVICE LATERAL CONFIGURATIONS AND FAULTS

	SKYLINE BASIN	MISSOURI BASIN
Service Laterals Tested & Inspected	31	86
CONFIGURATIONS (See Fig 6-1)		
#1	0	26
#2	20	50
#3	11	10
Property Line Bends	17	1
CLEANOUTS (CO)		
Needed For Inspections	31	60
Existing CO Found	31	44
Useable For Inspections	4	6
TYPE PIPE		
On Private Property		
Mortar Joint Concrete	0	37
Rubber Ring Concrete	27	13
Orangeburg	0	28
Cast Iron	0	4
PVC	4	4
In Public R.O.W.		
Mortar Joint Concrete	0	36
Rubber Ring Concrete	27	13
Orangeburg	0	28
Cast Iron	0	4
PVC	4	5
FAULTS		
Services Air Tested	31	78
Services Faulty	28	62
Tees Air Tested	28	77
Tees Faulty	19	77
Services Had:		
Faulty Tee or Riser	19	85
Broken Pipe (other than riser)	2	4
Egg Shaped Pipe	0	14
Leaking Joints	27	61
Root Intrusions	1	53

C. SERVICE LATERAL ACCESS

There are only three ways to gain access to the service lateral for testing, inspection and repair work. They are:

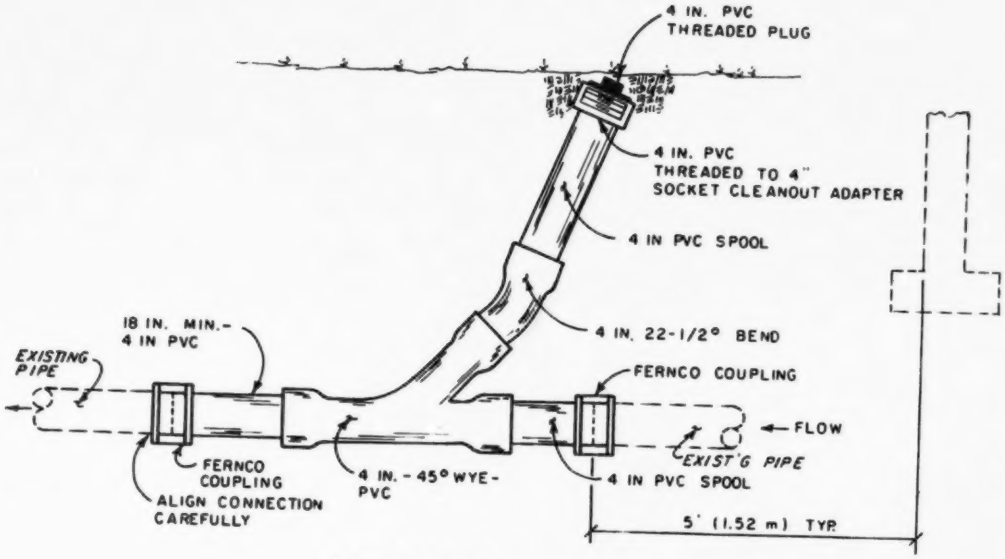
1. Access Through a Cleanout

Service lateral cleanouts on the Skyline and Missouri projects were located typically within 5 ft (1.52 meters) or 6 ft (1.83 meters) of each building served by a service lateral. Sometimes cleanouts were installed also where service laterals have 90 degree bends. In Oregon, most plumbing regulations require that a cleanout be installed on the service lateral pipe outside of the building. These regulations have not always been enforced and, consequently, many buildings have no cleanout outside the building. Many cleanouts incorporate radical bends or small diameter risers or caps which preclude the entry of TV inspection equipment, air testing equipment, etc. In most cases where access to a service lateral was gained through a cleanout, new cleanouts were installed. All such cleanouts were installed by hand without a backhoe. Few service laterals were more than 3 ft (0.91 meter) deep adjacent to the building. Two men with shovels averaged about four to five cleanout installations per day. Figure 6-2 shows a typical cleanout installed on an existing service lateral pipe. The configuration and installation is important as it is difficult to get testing and inspection equipment through the cleanouts if they are not properly installed and aligned.

2. Dig Ups

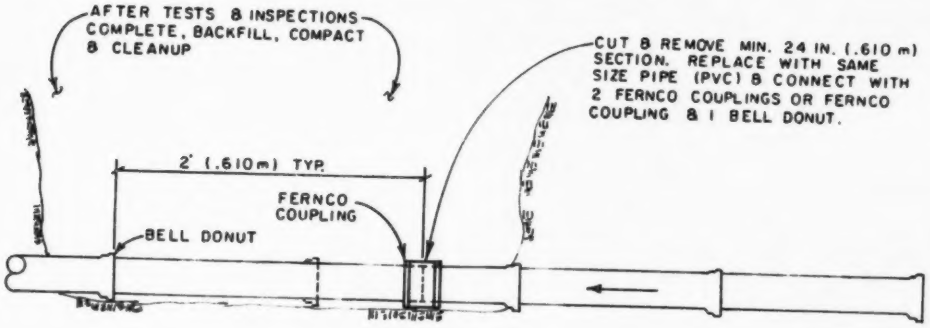
The second common way to gain access to the service lateral was to dig up the service lateral piping at a convenient location, section it, and then do any testing, inspection or repair work from that access. This type of access (see Figure 6-2) is particularly appropriate if it is already known that the service lateral is faulty and needs to be repaired. In that situation, inspections are usually done to determine where and what repairs need to be made. Thus, the dig up, inspection work, and repair work all can be done together.

When all service laterals in an area are being systematically tested and inspected, however, using dig ups for access has some disadvantages. Excavations need to be left open long enough to allow the testing, inspection, and repairs to be done. On a major job where many service laterals are being tested and repaired, it is difficult to schedule all of these operations so that the excavations can


4 IN. PVC
THREADED PLUG
4 IN. PVC
THREADED TO 4"
SOCKET CLEANOUT ADAPTER
4 IN PVC SPOOL
4 IN. 22-1/2° BEND
18 IN. MIN.-
4 IN PVC
EXISTING PIPE
FERNCO COUPLING
FLOW
EXIST'G PIPE
FERNCO COUPLING
4 IN. - 45° WYE-PVC
4 IN PVC SPOOL
ALIGN CONNECTION CAREFULLY
5' (1.52 m) TYP.

(1 inch = 2.54 cm)

SERVICE LATERAL CLEANOUT


AFTER TESTS & INSPECTIONS COMPLETE, BACKFILL, COMPACT & CLEANUP
CUT & REMOVE MIN. 24 IN. (.610 m) SECTION. REPLACE WITH SAME SIZE PIPE (PVC) & CONNECT WITH 2 FERNCO COUPLINGS OR FERNCO COUPLING & 1 BELL DONUT.
2' (.610m) TYP.
FERNCO COUPLING
BELL DONUT

DIGUP & SECTION PIPE

FIGURE 6-2
ACCESS TO A SERVICE LATERAL FOR TESTING & INSPECTION

be closed within a reasonable period of time. Open excavations in most areas are a hazard and must be carefully barricaded or be covered with plywood or sheet steel to guard against accident or injury.

3. Access from Within the Sewer Main

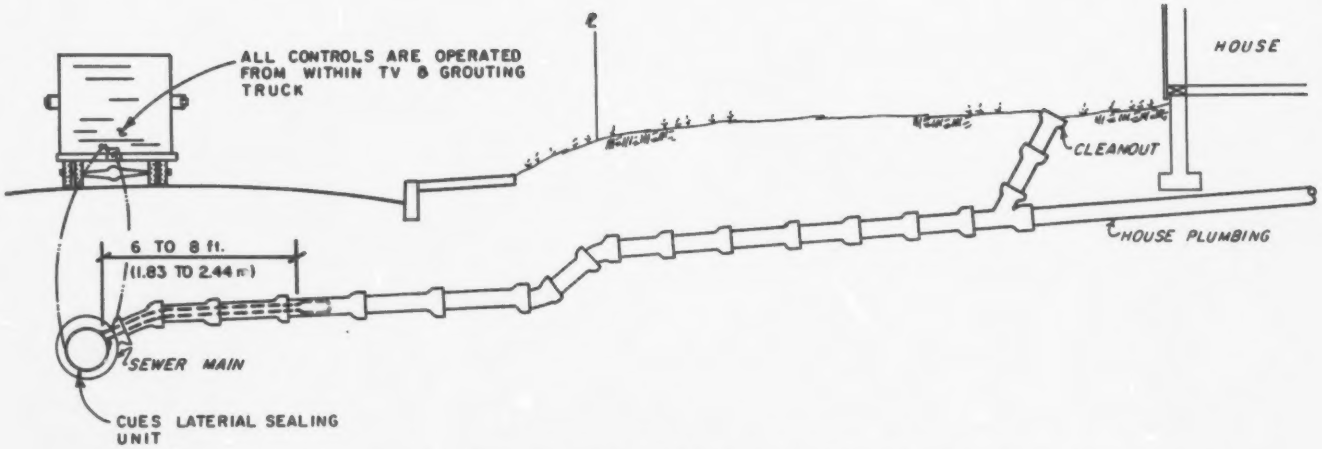
The only equipment presently available allowing access into service laterals from within the sewer main is the Cues Lateral Sealing System. This is a unit (see Figure 6-3) which is inserted into the sewer main at a manhole, and is towed into position at the connection of a service lateral to the main, and then inflates a sleeve into the service lateral piping. The sleeve typically extends 6 ft (1.83 meters) to 8 ft (2.44 meters) up the service lateral pipe where it then seals against the service piping. It can air test the lower 6 ft (1.83 meters) to 8 ft (2.44 meters) of the service lateral pipe together with the connection to the main. If the air test fails, it can chemically grout faults in this portion of the service lateral pipe.

This equipment is ideally suited for systematically testing and repairing service lateral pipes. No property owner authorizations, work on private property, or open excavations are required. The work can be done as an intrical part of a sewer main sealing program.

The disadvantages are that the equipment only tests or repairs the lower few feet of each service lateral and, because there is no way to inspect the pipe to be repaired, crushed or broken pipes not suitable for repair by grouting may be temporarily sealed. Also there can be difficulties in getting the inflatable sleeve to extend through sharp bends.

In summary, installing cleanouts and using those cleanouts for access has a number of advantages. Permanent access to the service lateral is provided. The testing, inspection and repair of the entire service lateral can follow in a logical progression. The cleanout is then available for any later inspections, retests, or maintenance work. Because cleanouts are normally located on private property, property owner authorization and/or cooperation is needed to get the cleanouts properly installed and to use them for access.

Digging service laterals up and sectioning them for access is appropriate in some circumstances. For systematic testing and inspection of service laterals, this access can


ALL CONTROLS ARE OPERATED FROM WITHIN TV & GROUTING TRUCK
℄
HOUSE
CLEANOUT
HOUSE PLUMBING
6 TO 8 ft.
(1.83 TO 2.44 m)
SEWER MAIN
CUES LATERIAL SEALING UNIT

Step 1 Cues Lateral Sealing unit is pulled through the sewer main until centered over opening for service lateral.

Step 2 Center of unit is rotated until opening for inflatable sleeve is aimed toward service lateral.

Step 3 Air pressure is applied to inflatable sleave causing it to extrude into service lateral. When sleave is fully extended, air pressure within it seals the upper end against the walls of the service piping.

Step 4 The end elements on the body of the unit is inflated, sealing against the walls of the main. Air is then introduced into the annular space between the inflated sleave and the service piping, the tee and several feet of service lateral piping is air tested.

Step 5 If the air test fails, chemical grout is pumped into the annular space to seal any leaks.

Step 6 An air test is then performed to determine that the seal is complete.

Step 7 The sleave is deflated and is retrieved into the sealing unit.

FIGURE 6-3

CUES LATERAL SEALING UNIT

be difficult. Frequently the excavation must be left open for up to two weeks before all testing, inspection and repair activities can be completed. This can be hazardous and result in citizen complaints. Once the initial work is done, if access is needed to reinspect or retest the piping, the excavation must be made again.

The Cues Lateral Sealing System has an obvious advantage because access is gained from within the sewer main. The equipment can only test or seal the downstream few feet of service lateral. In addition, this unit is available for use only in 8 in. (20.32 centimeters) mains. The service laterals sleeves are available for 4 in. (10.16 centimeters) and 6 in. (15.24 centimeters) service piping but, if more than one size service lateral pipe is found in an area, equipment modifications must be made to test and seal both sizes.

Each type of access has its advantages and disadvantages, and each will have its applications in rehabilitating many sewer basins. On the Missouri Basin Rehabilitation Project, for instance, if the project were to be done again, each type of service lateral access would be used.

D. INSPECTION METHODS

There are only two methods apparently being used for inspecting service lateral pipes. They are:

1. Small Diameter TV Inspection Unit

The small diameter TV camera for service lateral inspection is shown in Figure 4-7 and in Figure 6-4. These units are built in England, but are available in the United States. The camera should be skid mounted or otherwise protected from damage. Typically, the camera is inserted into a service lateral pipe from a cleanout or an open excavation. Flexible fiberglass rods are used to push the camera up or down the service lateral pipe. The camera sometimes cannot be pushed around abrupt bends in service lateral piping and this has prevented complete inspection of some laterals. Also, the configuration of the skid assembly is important. Occasionally the camera is pushed through misaligned pipe joints or into a larger pipe. If the skid assembly is not properly designed, it will catch on rough edges preventing retreival of the camera equipment.

TABLE 6-2
SERVICE LATERAL ACCESS

		ADVANTAGES	DISADVANTAGES
1.	Cleanout	a. Access is permanent. b. Scheduling of testing and inspections easier. c. Can make inspections and retests after repairs made. d. Access available for later maintenance.	a. Requires property owner cooperation. b. Potential liability and problems of working on private property. c. Access may be some distance from main making testing, inspections and repairs of lower part of service lateral difficult.
	Average Costs:	Administration to obtain property owner authorization - 3 man hours ($90), clean out installation ($132)	
2.	Dig Up	a. Do not usually need to enter private property or obtain property owner permission. b. Sometimes access is incidental to repair of known faults. c. Can test and inspect in both directions from dig up. This is usually easier than working from one end.	a. Excavation must be left open until all testing, inspection or other such work is done. b. Must re-excavate if additional work or inspections required. c. Scheduling testing and inspection tasks more difficult.
	Average Costs:	Dig up, Section pipe, Backfill and Surface Replacement - $200	
3.	Cues Method	a. No excavation or property owner authorization. b. Testing and repair done as single operation. c. Tests and repairs most critical portion of service lateral.	a. Only addresses lower six to eight ft (1.83m - 2.44m) of service lateral. (Range may soon be extended) b. Will not repair all types of faults. c. Work is done blind, so the nature of faults is not known.
	Average Costs:	No direct access cost.	

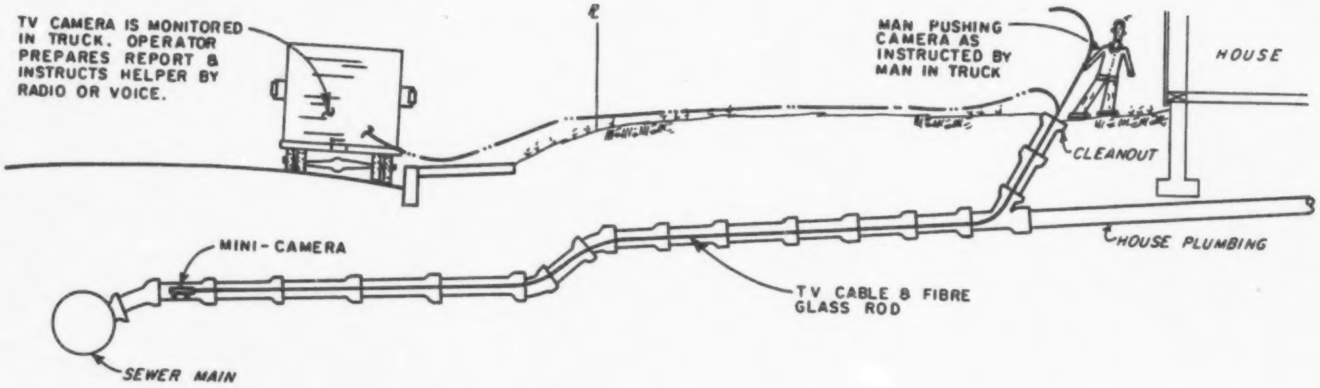

TV CAMERA IS MONITORED IN TRUCK. OPERATOR PREPARES REPORT & INSTRUCTS HELPER BY RADIO OR VOICE.
℄
MAN PUSHING CAMERA AS INSTRUCTED BY MAN IN TRUCK
HOUSE
CLEANOUT
HOUSE PLUMBING
MINI - CAMERA
TV CABLE & FIBRE GLASS ROD
SEWER MAIN

FIGURE 6-4

INSPECTING SERVICE LATERAL WITH MINI - CAMERA

For the Skyline and Missouri projects, the TV monitor was installed in a mainline TV inspection truck. The monitor was connected to a video tape machine so that all inspections could be recorded for a later review.

2. Visual Inspections

Sometimes the condition of service pipe is evident when the pipe is uncovered. In the case of egg shaped Orangeburg pipe, for instance, visual inspection will allow decisions regarding the type of repair to be made.

There presently is no service lateral inspection equipment which will enter lateral piping from within the sewer main.

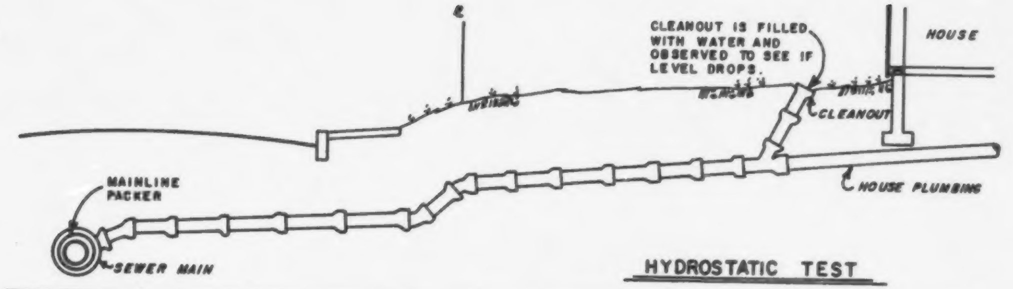
Some have questioned the necessity of inspecting service lateral piping before making repairs. Sometimes inspection is not necessary. For instance, if records show all service laterals in an area were built of piping known to be deficient, and that pipe is to be replaced, there is no good reason for inspecting before replacement. For example, in the Skyline and Missouri Basins, however, the condition and configurations of service laterals varied considerably from installation to installation. Some laterals needed complete repair or replacement, while others needed repair in only one or two places. In these situations, or in situations where property owners are responsible for the piping on private property and the sewer agency is responsible for piping within the street right-of-way, good inspections are necessary to determine what must be done, how to do it, and who is responsible.

E. TESTING METHODS

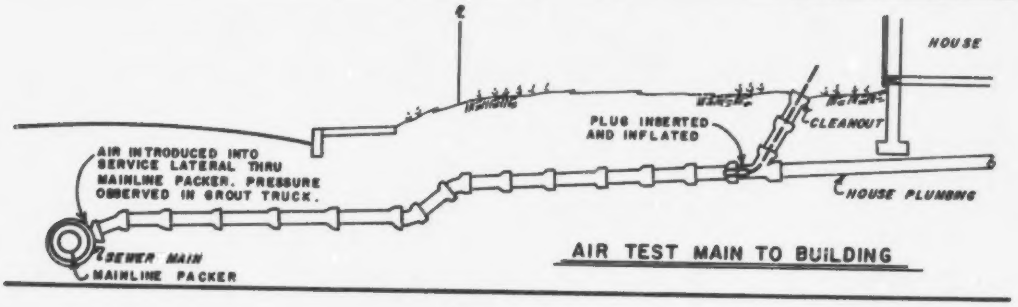
There are several techniques for determining if service lateral piping is watertight. In time, new methods and new equipment may be developed. Methods (see Figure 6-5 and Table 6-3, page 80) used for the Skyline and Missouri projects were:

1. The Hydrostatic Test

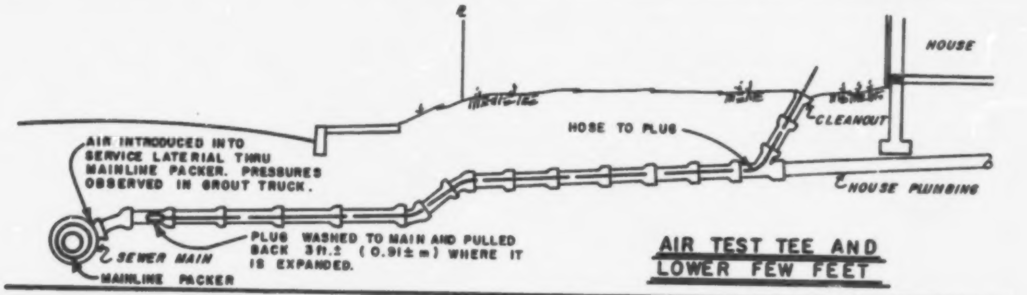
The hydrostatic test is done by positioning a mainline packer over the service lateral connection to the main, and expanding the packer elements to block the service lateral connection. Then the service lateral pipe is filled with water, usually from the cleanout. Care must be taken that additional water from plumbing is not introduced during the test. Typically, the service lateral pipe is filled with


℄
CLEANOUT IS FILLED WITH WATER AND OBSERVED TO SEE IF LEVEL DROPS.
HOUSE
CLEANOUT
MAINLINE PACKER
HOUSE PLUMBING
SEWER MAIN

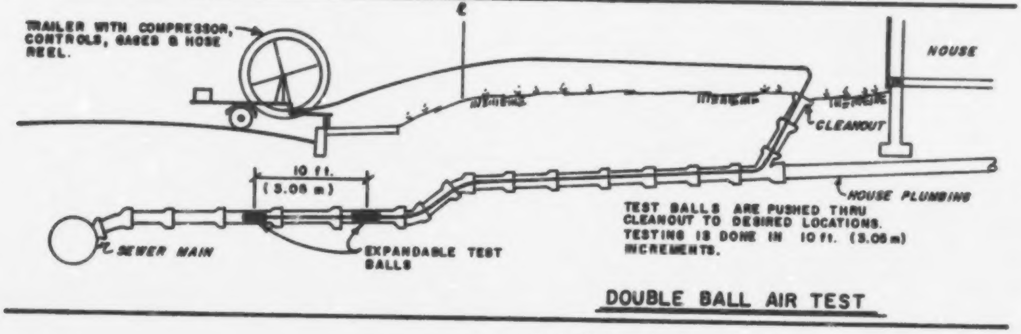
HYDROSTATIC TEST


℄
HOUSE
PLUG INSERTED AND INFLATED
CLEANOUT
AIR INTRODUCED INTO SERVICE LATERAL THRU MAINLINE PACKER. PRESSURE OBSERVED IN GROUT TRUCK.
HOUSE PLUMBING
SEWER MAIN
MAINLINE PACKER

AIR TEST MAIN TO BUILDING


℄
HOUSE
HOSE TO PLUG
CLEANOUT
AIR INTRODUCED INTO SERVICE LATERIAL THRU MAINLINE PACKER. PRESSURES OBSERVED IN GROUT TRUCK.
HOUSE PLUMBING
PLUG WASHED TO MAIN AND PULLED BACK 3ft.± (0.91± m) WHERE IT IS EXPANDED.
SEWER MAIN
MAINLINE PACKER

AIR TEST TEE AND LOWER FEW FEET


TRAILER WITH COMPRESSOR, CONTROLS, GAGES & HOSE REEL.
℄
HOUSE
CLEANOUT
10 ft.
(3.05 m)
HOUSE PLUMBING
TEST BALLS ARE PUSHED THRU CLEANOUT TO DESIRED LOCATIONS. TESTING IS DONE IN 10 ft. (3.05 m) INCREMENTS.
SEWER MAIN
EXPANDABLE TEST BALLS

DOUBLE BALL AIR TEST

FIGURE 6-5
SERVICE LATERAL TESTING TECHNIQUES

water until the cleanout riser fills. After the pipe soaks for 20-30 minutes, the water level in the cleanout riser is measured periodically to determine whether the piping is watertight. Rules of how much lost water constitutes a failure need to be established. The test is relatively simple and tests both the service lateral and the main connection. The test is time consuming. The process requires upstream access, and occupies a mainline grouting crew for approximately one hour per test.

2. Air Test, Main to Building

This test is performed like the hydrostatic test described above, except the service lateral piping is plugged just downstream from the cleanout. A mainline packer is positioned over the service lateral tee and air is introduced from the packer for the air test. Typically, the isolated pipe is pressurized to between 5 and 8 psi (3.44 and 5.52 Newtons per square centimeter). The test is satisfactory if the air pressure drops no more than 0.5 psi (.345 Newtons per square centimeter) in 30 seconds. This test takes less time than the hydrostatic test, but requires a mainline grouting crew. This test does not locate leaks within the service lateral, only indicates if the lateral is watertight.

3. Air Test, Tee and Lower Few Feet of Service Lateral Pipe

This test isolates the tee and lower few feet of service lateral to determine if there are faults there. As this is a particularly critical portion of the service, and one frequently found faulty, this portion must often be tested alone. An expandable rubber plug is pushed or washed down the service lateral pipe from a cleanout or dig up until it reaches the sewer main and can be viewed by a mainline TV camera. It is then pulled back into the service lateral 2 to 5 ft (.609 meter - 1.52 meters) and is expanded. The mainline packer is then pit positioned over the service lateral tee, is expanded, and an air test is performed on this isolated portion of service lateral piping.

4. Double Ball Air Test

The double ball air test apparatus was used extensively on the Missouri Basin project. Figures 6-6 and 6-7 show this apparatus. Service lateral access can be through a cleanout or an open excavation. The double ball test unit

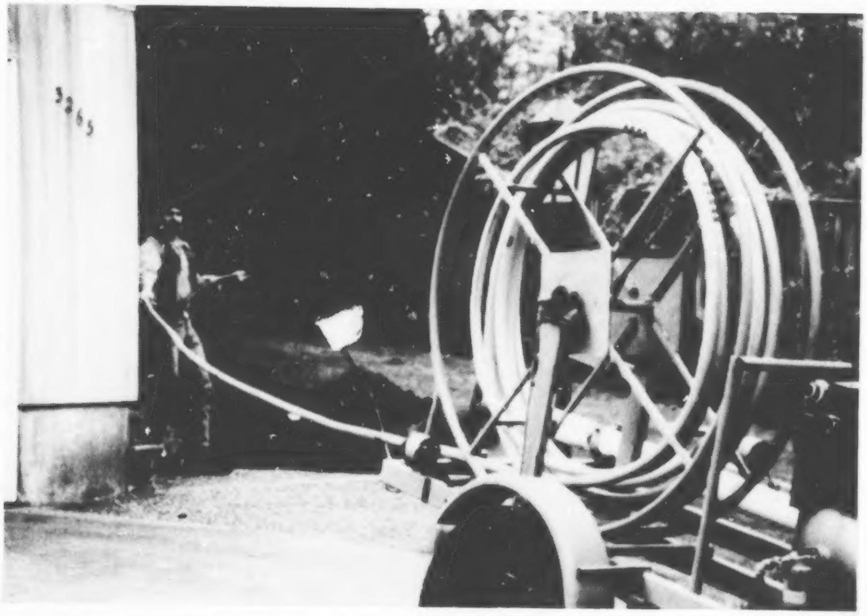


Figure 6-6 - Double Ball Air Test Unit

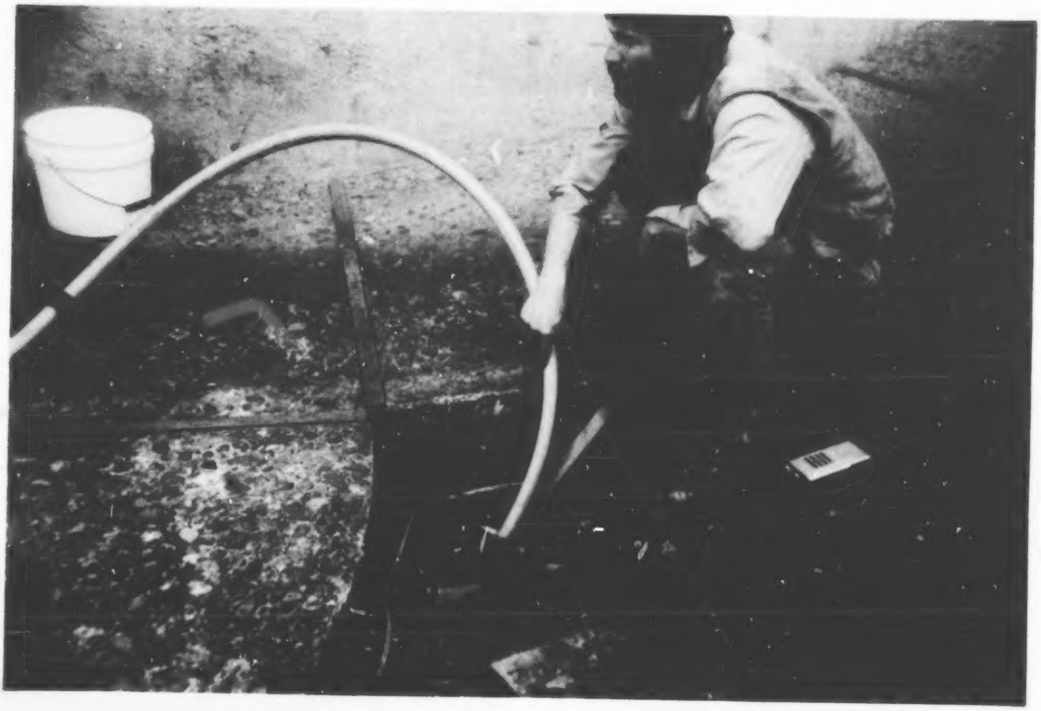


Figure 6-7 - Air test being performed. Access thru cleanout.

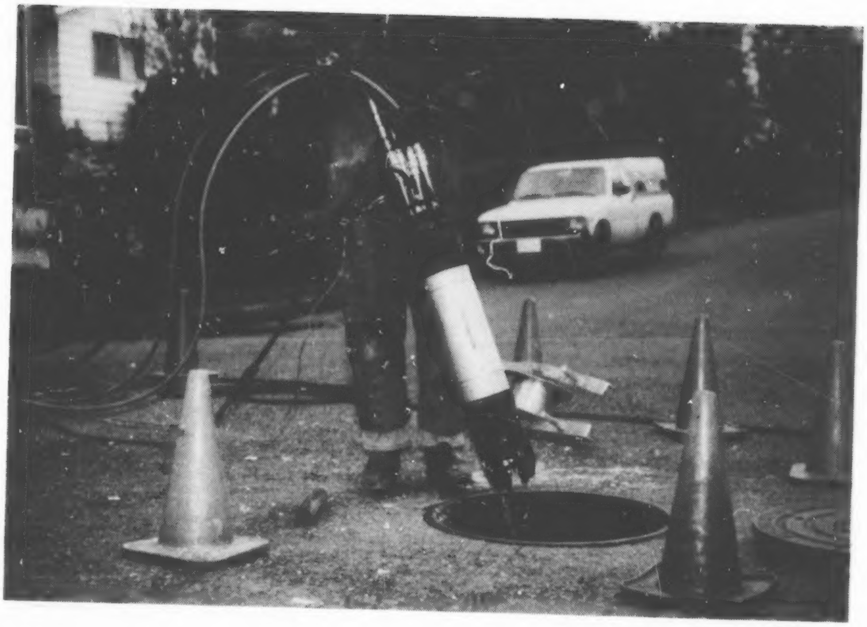


Figure 6-8

Cues Lateral Sealing Unit
as it enters manhole.

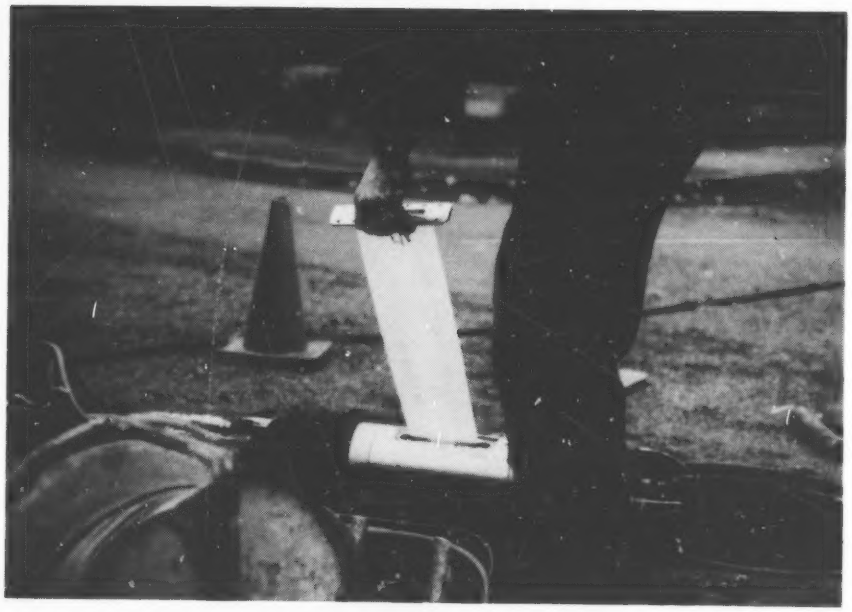


Figure 6-9 and 6-10 - New inflatable sleeve being installed in Lateral Sealing Unit.

TABLE 6-3
SERVICE LATERAL TESTING METHODS

	APPROXIMATE COST	ADVANTAGES	DISADVANTAGES
1. Hydrostatic Test Test	$125	a. Simplicity b. Tests tee and service lateral.	a. Requires upstream access. b. Must be sure no actual sewage is flowing from building. c. Can be relatively time consuming to run test. d. Requires packer in main. e. Does not locate leak.
2. Air Test, Main to Excavation or Cleanout	$100	a. Simplicity. b. Tests tee and service lateral.	a. Requires upstream access. b. Requires packer in main. c. Doesn't locate leak.
3. Air Test, Tee and Lower Two to Five Ft (.61m - 1.52m) Service Lateral	$125	a. Identifies leaks in most critical portion of service lateral.	a. Requires upstream access. b. Requires TV inspection first. c. Somewhat time consuming.
4. Double Ball Air Test	$72.50	a. Reasonably simple. b. Locates leaks. c. Does not require packer in main.	a. Requires upstream access. b. Requires TV inspection first. c. Does not test tee at main. d. Not suitable for laterals with more than one size pipe.
5. Cues Lateral Sealing System	$290*	a. No separate service lateral access required. b. Tests tee and lower portion of lateral. c. Makes repairs also.	a. Tests only six to eight ft (1.83 m - 2.44 m) service lateral.

* Test only. From Washington Suburban Sanitary Commission experience.

is pushed into the service lateral and tests are performed at 10 ft (3.05 meters) intervals, thereby determining approximately where service lateral leaks or faults exist. Service lateral pipe must be TV inspected before air testing so that the expandable plugs are not accidentally pushed into the mainline pipe where inflating the test balls destroys them. Double ball air tests for a service lateral usually take about 30 minutes. This equipment will not test the connection at the main or the downstream two feet of service lateral pipe. As the service lateral test apparatus is much less expensive than the mainline grouting equipment utilized for the first three tests described above, the cost of double ball testing is less than the first three types of tests. The double ball test unit rents for $25 an hour versus $60 an hour for a TV/grout unit.

5. Cues Lateral Sealing System

Figures 6-8, 6-9 and 6-10 show the Cues Lateral Sealing System. As described earlier, this system gains access to the service lateral from within the sewer main and can test the lower 6 to 8 ft (1.83 meters - 2.44 meters) of the service lateral pipe, and the main connection.

Some installations do not need to be tested. For instance, if pipe inspections revealed broken pipes, visible leaks or root intrusion, there may be little reason to leak test. Simply proceed with rehabilitation or replacement. Except for the hydrostatic test, all service lateral testing methods and techniques will most likely be utilized on future Salem rehabilitation projects. Where the sewer agency must learn whether the service lateral is faulty on private property or within the public right-of-way, as previously indicated the double ball air test unit has particular application. It also could logically be utilized in testing new service laterals either immediately or several months after their installation.

F. REPAIR METHODS

Several types of service lateral repairs were utilized for the Skyline and Missouri projects. The repair methods used are similar to methods commonly used for main rehabilitation. They are (see Table 6-4, page 98):

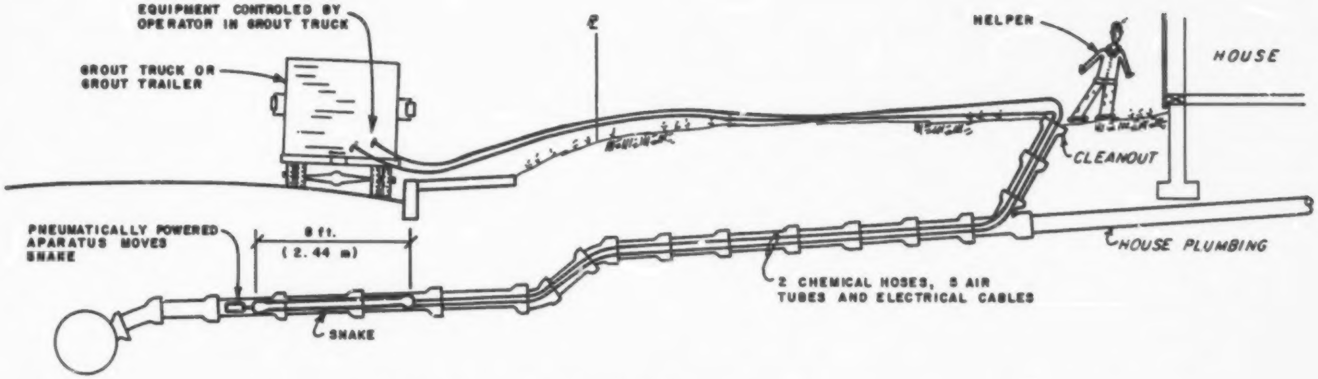
1. Grouting

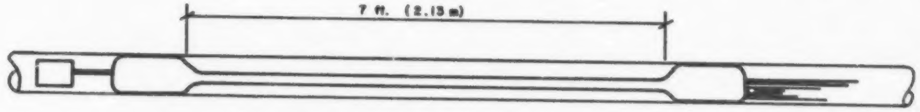
Three types of grouting equipment for service laterals were utilized in these projects.

a) The Cues Lateral Sealing System was used on the Missouri project. This equipment was developed by Cues and others for the Washington Suburban Sanitary Commission near Washington D.C. Its use on the Missouri project was the first time the equipment had been used outside the Washington D.C. area. Originally, 16 service laterals were to be tested and repaired with this equipment. The equipment and a Cues technician arrived in Salem a few days before a rare Salem snow storm and extended freeze. Several days were spent adapting the Cues equipment to operate with a Gelco grouting truck. Then, attempts were made to use the lateral sealing system in Missouri Basin lines 40, 43, 58 and 59. Progress was slow. There were mechanical problems and Gelco technicians were not fully familiar with the equipment. The inflatable sleeve would not go up some service laterals. Later some were found to be configuration #1 installations with badly broken and misaligned risers. The inflatable sleeve would go up other service laterals, but some could not be sealed. These, too, were later determined to be faulty beyond repair by grouting.

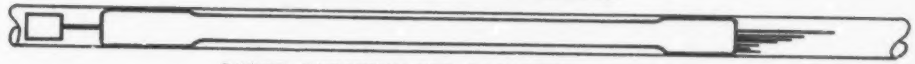
Next it snowed and froze. For nearly a week, trucks could not get to the work site. Christmas came and went. Then it thawed, and flows in section 43 were so high that the unit could not be used there. In all, 12 service laterals were tested with the Cues unit. All failed the test, and sealing was attempted. Six seals appeared to be satisfactory and apparently eliminated the majority of the service lateral flow. The six other services sealed with the Cues unit later had to be dug up and repaired by other means. Most of these were configuration #1 and the riser pipe was faulty, but at least three services were also found to be leaking extensively upstream of the initial repairs upon the completion of Step B repairs.

b) The Westech/Gelco Snake was under development in 1980, but was first field demonstrated on the Skyline Rehabilitation Project. During that project, a series of mechanical difficulties were experienced and various modification and improvements to the equipment were made. By the completion of Step B in spring 1982, the snake was


EQUIPMENT CONTROLED BY OPERATOR IN GROUT TRUCK
GROUT TRUCK OR GROUT TRAILER
℄
HELPER
HOUSE
CLEANOUT
HOUSE PLUMBING
PNEUMATICALLY POWERED APARATUS MOVES SNAKE
8 ft. (2.44 m)
SNAKE
2 CHEMICAL HOSES, 5 AIR TUBES AND ELECTRICAL CABLES



SNAKE EXPANDED FOR TESTING



SNAKE EXPANDED FOR GROUTING

PROCEDURES:

1. INSERT SNAKE IN CLEAN OUT & HAVE IT CRAWL TO MOST DISTANT POINT NEEDING TO BE GROUTED.
2. EXPAND ENDS OF SNAKE & AIR TEST PIPE SECTION SO ISOLATED.
3. IF AIR TEST FAILS, FUTHER EXPAND SNAKE & PUMP GROUT.
4. DEFLAT SNAKE TO TEST POSITION & RETEST PIPE. REPEAT GROUTING STEPS IF NECESSARY.
5. DEFLATE SNAKE ENTIRELY, PULL UNIT BACK TO NEXT DESIRED POSITION.
6. REPEAT STEPS 2-5.

FIGURE 6-11
GROUTING WITH WESTECH/ GELCO SNAKE

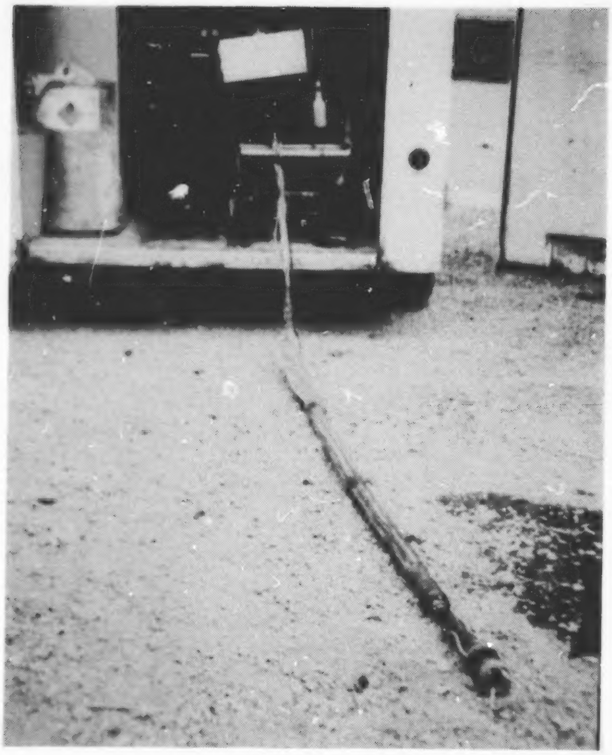


Figure 6-12
Snake & Trailer

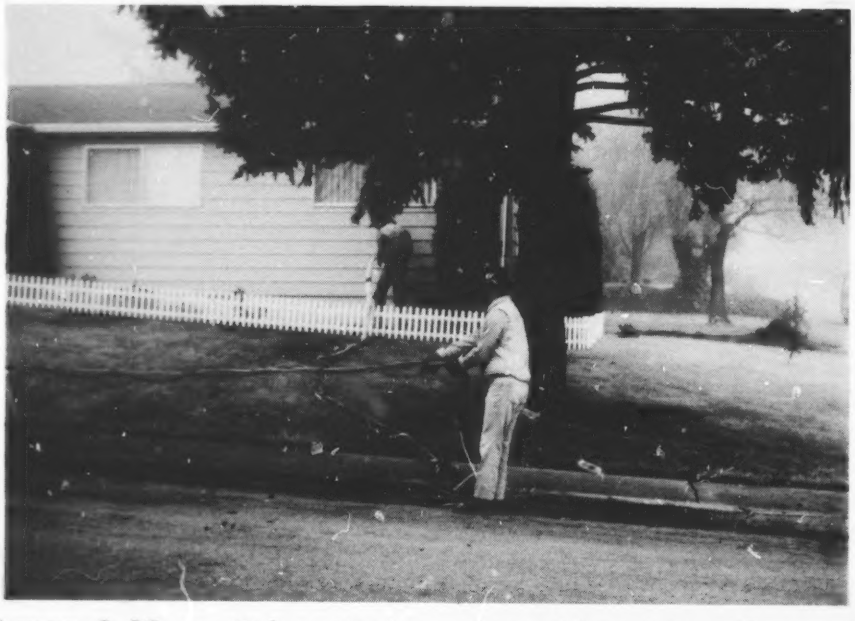


Figure 6-13 - Using Snake - Inserting into cleanout.

operating satisfactorily and seemed to be adequately sealing leaking rubber ring jointed concrete service lateral pipes. Between spring 1982 and fall 1983, this equipment was used on other projects, experience was gained, and minor equipment improvements were made. Thus, by Fall 1983 when Step B - Missouri Basin work started, Gelco technicians had considerable experience operating this equipment. They had learned what faults and piping the equipment would repair, and where its use was not appropriate.

The Westech/Gelco snake consists of an 8 ft (2.44 meters) long cylinderical rubber inflatable tube which is connected to a pneaumatically operated propulsion apparatus. See Figures 6-11, 6-12 and 6-13. The unit is inserted into a service lateral pipe through a cleanout or open excavation. The propulsion equipment is then operated until the unit crawls to the most distant faulty piping previously located by double ball testing. The unit is then inflated and approximately 7 ft (2.13 meters) of service lateral piping is isolated for an air test. If the air test indicates leakage in the isolated section of pipe, acrylamide grout is pumped to seal the faults. The apparatus is then deflated, reinflated and another air test is run to determine if the seal is adequate. If so, the unit is pulled back approximately 7 ft (2.13 meters) and the process is repeated.

The option exists for using the snake to air test service laterals rather than the double ball air test unit. This usually is not done because:

1) The double ball unit is quicker, cheaper and easier to use.

2) Occasionally, the rubber elements are damaged. It costs $600 for snake elements versus $50 for test ball elements.

3) The double ball unit will reach areas where the snake cannot get to.

The snake has proved suitable to repair joint leaks or pipe shears in structurally sound piping. It should not be used where there is significant root intrusion or where piping is broken or longitudinally cracked. The equipment is particularly appropriate where there are a few faulty joints in an otherwise satisfactory service lateral pipe. This unit cannot test or repair the main connection or piping within 2 ft (.61 meter) of that connection, nor will it traverse around 90 degree bends and is stopped by some 45 degree bends.

The snake was used to repair 21 services in the Skyline Project and 27 services in the Missouri Project. Two Skyline repairs failed. After added experience and equipment improvements, no Missouri snake repairs are known to be faulty.

c) The Plug and Grout Technique was utilized on both the Skyline and Missouri projects. The principal application of this technique is in testing and repairing service lateral connections to the main and the first few feet of the pipe upstream from the main.

An inflatable rubber plug with extension hose is pushed or washed down the service lateral pipe until it enters the main where viewed by the mainline TV camera. The plug is then retreived a few feet, usually 2 to 5 ft (.61 meter - 1.52 meters) and is expanded. The mainline packer is then positioned over the tee, is inflated, and the isolated pipe is air tested. If the air test fails, the entire isolated piping is filled with acrylamide grout. The plug is then removed and a high pressure pipe cleaner is sent down the service lateral pipe to clean out the grout plug and open the pipe. The rubber plug is then repositioned, as is the mainline pipe packer, and another air test is run to make certain that the seal is complete.

Eighteen of 19 faulty service lateral connections were repaired utilizing this technique on the Skyline Project. Approximately 54 such repairs were attempted on the Missouri Project. About 27 attempts failed, however. In almost all cases, broken configuration #1 connections requiring replacement were found. Most service laterals were found faulty at or immediately adjacent to the mainline connection, 68% in the

Skyline Basin and nearly 100% in the Missouri Basin. Thus, the plug and grout technique or the Cues Lateral Sealing System needs to be incorporated into most rehabilitation projects.

The plug and seal technique was used on the Skyline Project to seal up to 30 ft (9.14 meters) of a service lateral pipe. This proved expensive and not very satisfactory. Plugging and sealing 4 in. service lateral piping over 6 to 8 ft (1.83 meters - 2.44 meters) in length with the plug and grout technique is not recommended. It takes so long to pump the grout into a long section of pipe that grout either disipates through leaks or sets up within the pipe before adequately penetrating into outside soil materials. Consequently, surface seals which soon fail can result.

2. Polyethylene Liners (PE)

PE tubing has been used extensively in various localities to line faulty or leaking service lateral piping. Three and one half in. outside diameter (8.89 centimeters) class 1000 PE tubing was used to line 4 in. (10.16 centimeters) service laterals in the Missouri Basin. The original service piping needs to be reasonably straight to allow the insertion of a PE liner. Although the liner pipe is quite flexible and can be pushed through piping with deflected joints, the tubing usually cannot be pushed thru any manufactured bends. Therefore, if the original piping has bends, they must be located, dug up and removed for PE liner installation.

In other localities where PE lining of service laterals is done routinely, typically each service lateral is dug up at its connections to the main and to the building plumbing. The service lateral pipe is temporarily disconnected from the main and is removed far enough to allow the installation of the liner. The PE liner is then inserted into the service lateral pipe between these two points and is connected with appropriate bends and rubber couplings to both the main and the house plumbing.

On the Missouri project (see Figure 6-14), an attempt was made to minimize excavations next to the mains in the paved streets. Therefore, to install a PE liner, the service pipe was dug up and exposed in a convenient place. Often this excavation was located adjacent to the house where the cleanout would normally be installed, near the property line, or where the service lateral made an abrupt bend. The PE liner pipe was then inserted into the service lateral pipe and additional sections of PE liner were fused to the end of the liner as needed. Many service laterals were completely PE lined from an excavation next to the house, or the liner was installed in two directions from an intermediate excavation between the house and the main. The installation of liners proved to be easier than anticipated. Many liners could be pushed by hand into the existing service lateral pipe. Others needed to be "pursuaded" by laying a board over the end of the liner pipe and beating on it with a maul. Typically the liner pipe was connected to a new or existing cleanout adjacent to the house.

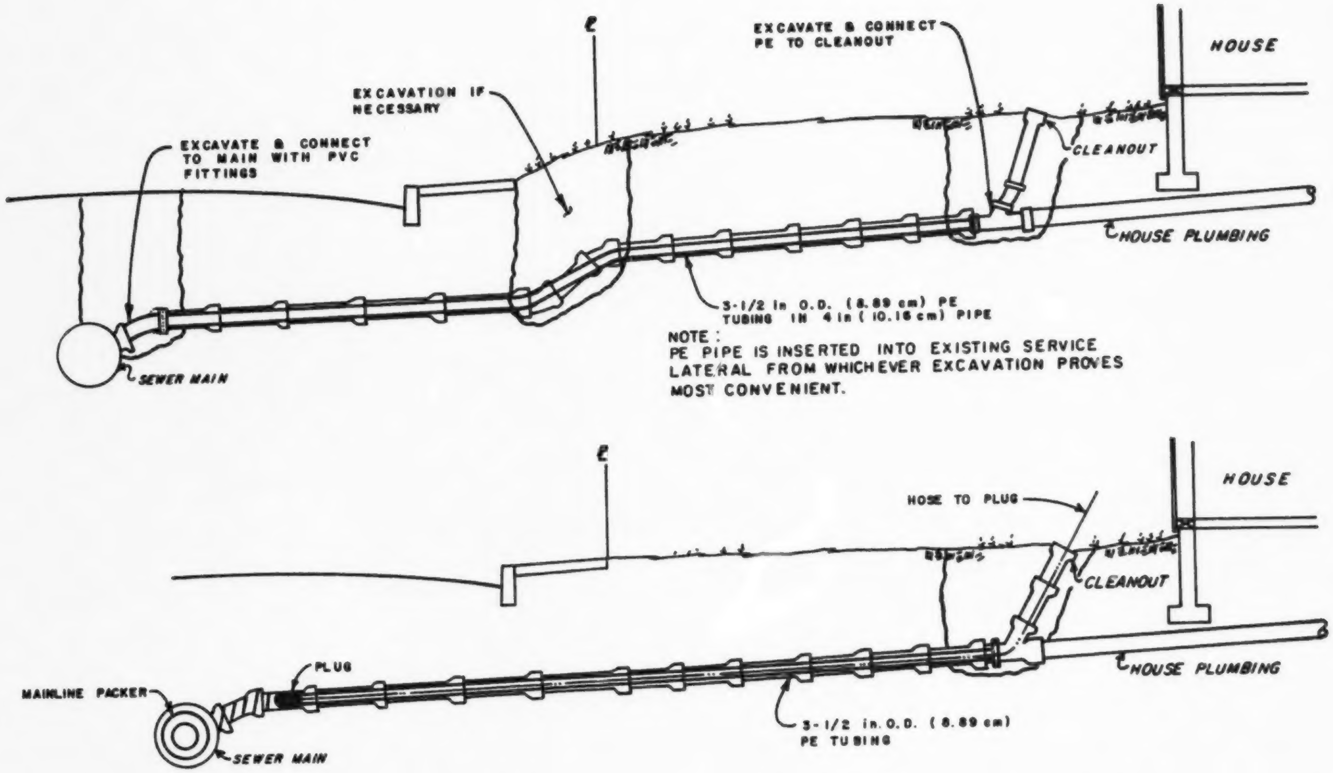
The connection at the main was made as follows:

Information and measurements from earlier service lateral TV inspections were used to determine how far the liner should be installed towards the main. It was stopped just short of the vertical bends in configuration #1 and #2 installations, and just short of the main in configuration #3 installations. Then, in conjunction with mainline grouting, a plug was positioned just inside the downstream end of the PE liner. It was expanded, the mainline packer was positioned over the main connection, and the mainline connection and the annular space around the outside of the liner pipe were filled with grout. The plug was then removed and a hydraulic cleaner was used to remove the grout plug from the bottom few feet of the service lateral. The plug was then reinstalled and an air test was run to make sure that the installation was watertight.

This procedure worked reasonably well except for configuration #1 and #2 installations where the pipes adjacent to the main were badly broken. Several installations were encountered where the service riser had to be dug up, removed and physically reconnected after the grouted connection failed.

Using PE liners requires some specialized equipment including the end trimming and heat fusion apparatus. If several service laterals are lined, installing PE liners can be an excellent way to rehabilitate faulty service laterals.

The liner pipe should last indefinitely. It is smooth, tough and relatively easy to install.



EXCAVATION IF NECESSARY
ℓ
EXCAVATE & CONNECT PE TO CLEANOUT
HOUSE
EXCAVATE & CONNECT TO MAIN WITH PVC FITTINGS
CLEANOUT
HOUSE PLUMBING
SEWER MAIN
3-1/2 in O.D. (8.89 cm) PE TUBING IN 4 in (10.16 cm) PIPE
ℓ
HOUSE
HOSE TO PLUG
CLEANOUT
HOUSE PLUMBING
PLUG
MAINLINE PACKER
SEWER MAIN
3-1/2 in. O.D. (8.89 cm) PE TUBING

NOTE:
PE PIPE IS INSERTED INTO EXISTING SERVICE LATERAL FROM WHICHEVER EXCAVATION PROVES MOST CONVENIENT.

ALTERNATE CONNECTION AT MAIN:

1. TUBING INSTALLED TO WITHIN 3 ft. (.91m) OF TEE AT MAIN.
2. PLUG PUSHED THRU CO TO NEAR THE END OF THE PE LINER. IT IS EXPANDED.
3. MAINLINE PACKER GROUTS TEE AND ANNULAR SPACE OUTSIDE PE LINER WITH ACRYLAMIDE GROUT.
4. AFTER REMOVING THE PLUG AND PACKER, A HIGH PRESSURE CLEANER IS INSERTED THRU THE C.O. AND USED TO CLEAN THE EXCESS GROUT FROM THE LOWER END OF THE SERVICE LATERAL

FIGURE 6-14
INSTALLING PE LINERS

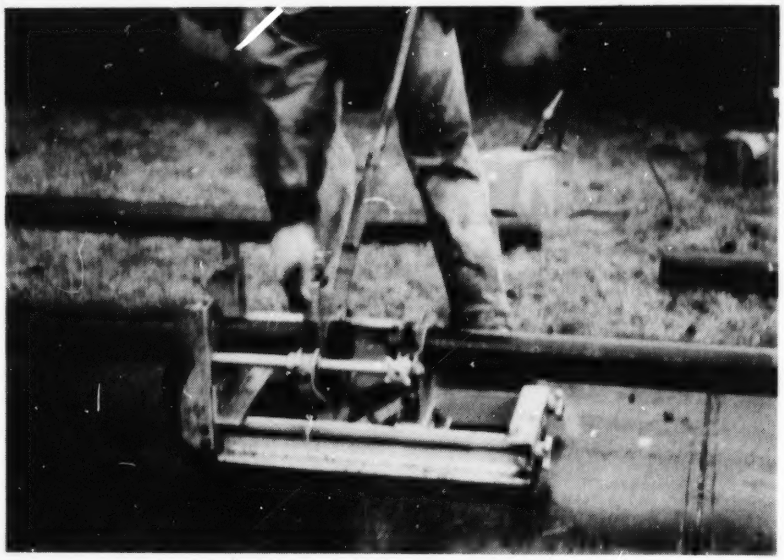


Figure 6-15 - Preparing to fusion weld liner tubing.

Figure 6-16 - "Pursuading" the liner.

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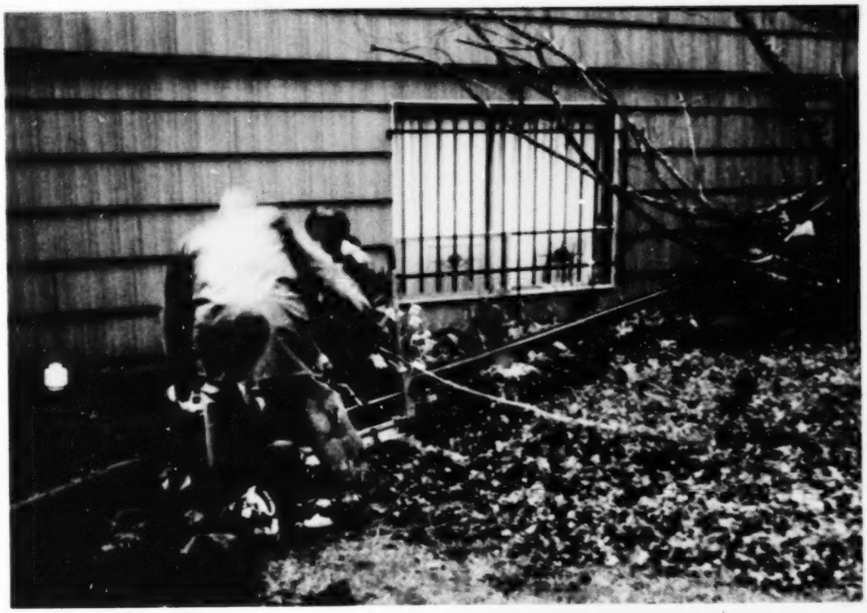


Figure 6-17 - Liner part way in, welding on some more.

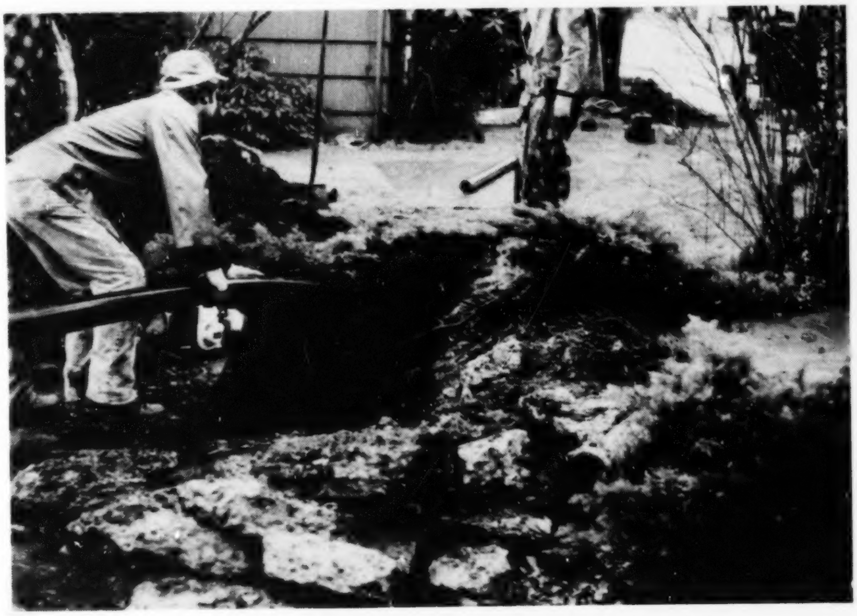


Figure 6-18
Excavation at property line. Liner installed both directions.

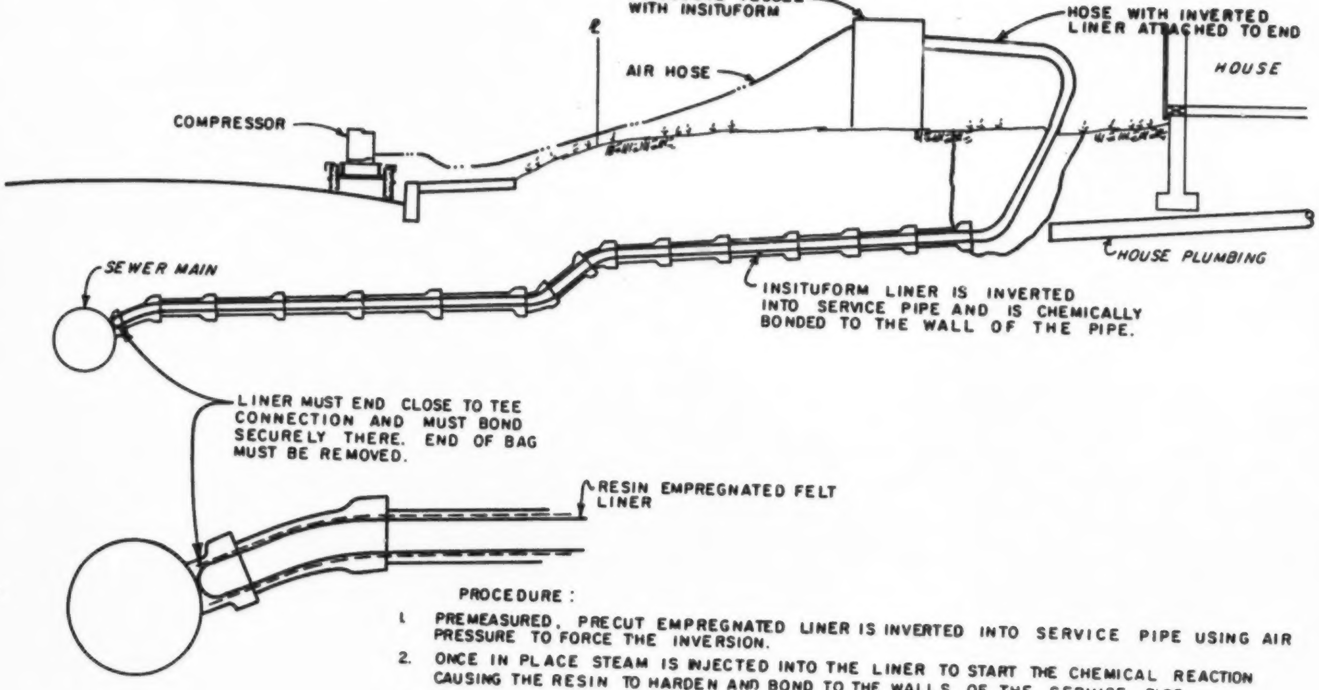
3. Insituform Liners

Six Missouri Basin service laterals were reconstructed with Insituform liners. Insituform is a patented process first developed in England for bonding a strong plastic felt reinforced liner to the inside wall of existing piping. The liner, called a sock, is a polyester fiber felt tube coated on one side with an impermeable material. These liners have been used extensively in rebuilding damaged pipe lines throughout the world. The felt liner is impregnated with liquid thermo-setting resin which is activated once the liner is in place within the damaged pipe line. Once the resin has been activated and cures, it bonds the liner firmly to the wall of the old pipe forming a new slick, strong, and impermeable liner within the old pipe. This process has been utilized only rarely within the United States for the rehabilitation of service lateral pipes.

If the procedures and techniques to effectively install Insituform liners within service lateral pipes can be developed, this process has many advantages. The liners can be installed in piping which is crooked, has bends, and is cracked or broken. Potentially Insituform liners can repair many of the worst and most inaccessible service laterals.

Service laterals present special challenges for the Insituform process. Ideally, the Insituform liner should be installed from a point near the house or property line where the service pipe can be uncovered easily. The liner needs to terminate at the main tee connection, and needs to seal against the existing piping walls there. Otherwise, water may run down the annular space between the pipe and the liner. The Insituform service lateral liners installed on the Missouri project were amongst the first installations of this type ever attempted. The results were mixed, but show promise. See Figure 6-19, 6-20 and 6-21.

Each service lateral chosen for Insituform liner was not suitable for grouting, was too crooked to line with PE, and was expensive to replace. Each service lateral pipe was uncovered at a convenient location usually near the building. The service pipe was then cleaned and carefully TV inspected to determine its length and to make sure that there were no obstructions within the pipe. A felt liner cut to length and impregnated with activated polyester resin was then delivered to the job site. The chemical reaction of the polyester resin was retarded by storing the impregnated liner in ice within a specially built container


PRESSURE VESSEL WITH INSITUFORM
HOSE WITH INVERTED LINER ATTACHED TO END
HOUSE
℄
AIR HOSE
COMPRESSOR
HOUSE PLUMBING
SEWER MAIN
INSITUFORM LINER IS INVERTED INTO SERVICE PIPE AND IS CHEMICALLY BONDED TO THE WALL OF THE PIPE.
LINER MUST END CLOSE TO TEE CONNECTION AND MUST BOND SECURELY THERE. END OF BAG MUST BE REMOVED.
RESIN EMPREGNATED FELT LINER

PROCEDURE :

1. PREMEASURED, PRECUT EMPREGNATED LINER IS INVERTED INTO SERVICE PIPE USING AIR PRESSURE TO FORCE THE INVERSION.
2. ONCE IN PLACE STEAM IS INJECTED INTO THE LINER TO START THE CHEMICAL REACTION CAUSING THE RESIN TO HARDEN AND BOND TO THE WALLS OF THE SERVICE PIPE.
3. THE SPECIAL "TEAR OUT" END OF THE "BAG" OR LINER AT THE MAIN IS REMOVED.

FIGURE 6-19
INSITUFORM LINER

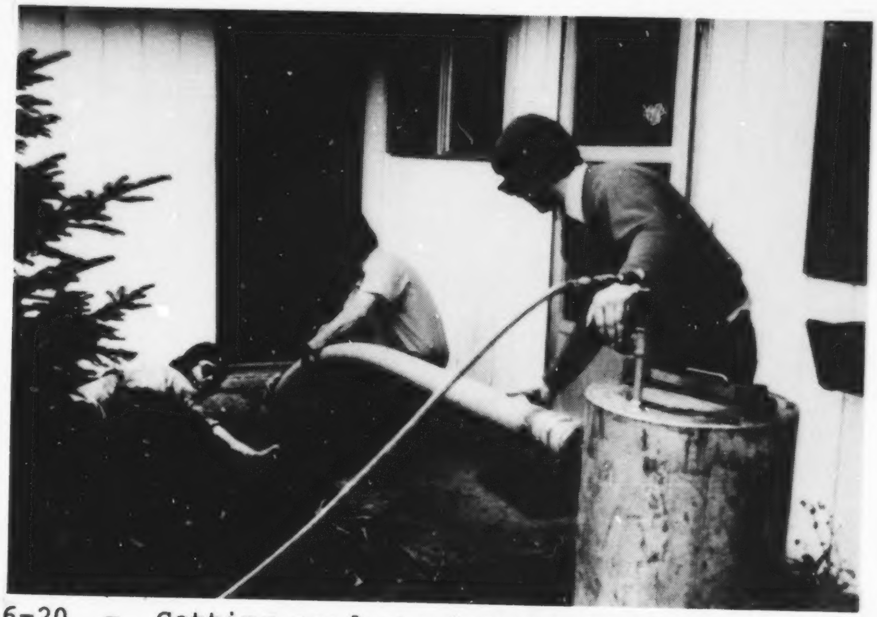


Figure 6-20 - Getting ready to install Insituform liner. Ice cooled liner is in air tank in foreground. End of liner is attached to green hose.

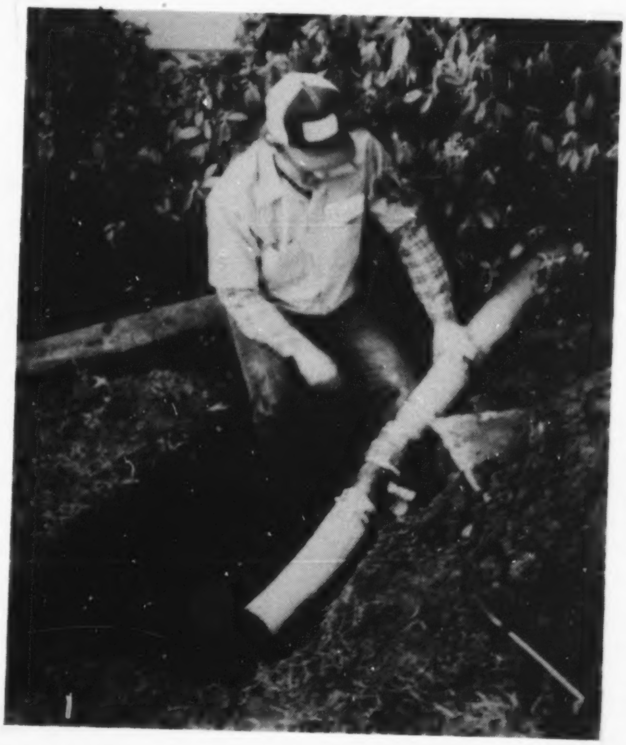


Figure 6-21
System is pressurized and sock is being inverted into service pipe.

as shown in Figure 6-20. Air pressure is used to force the impregnated liner into the service lateral pipe. This apparatus worked quite well, and once equipment was set up, most liners were quickly inverted into the service lateral pipe. This process usually took less than two minutes. Once the liner was within the existing pipe, it could not be moved. The inflated sock pressed firmly against the pipe walls. Once in place, steam was added to heat the liner, causing the polyester resins to rapidly harden.

Several difficulties were encountered. First, the liners stretch causing the end of the liner to extend past the tee connection and into the mainline pipe. Here sewage washes the impregnated resin from the felt liner causing that portion of the liner to remain soft and pliable. The liner within the service lateral pipe hardens and adheres tightly to the wall of the service lateral, but no suitable way to cut the soft excess liner from within the main was found. These had to be dug up at the main. Also, a way to remove the end of the liner sock once the sock has hardened in place must be found so that water can flow through the service lateral. Gelco experimented with tear out ends so that the end of the sock can be removed after it is in place. That innovation appears workable.

Problems obtaining an adequate seal between the liner and the existing pipe near the tee connection were also encountered. If the service lateral pipe is leaking substantially, water runs between the liner and the wall of the existing pipe. Unless the liner is sealed firmly against the wall of the existing pipe preventing that flow, the service lateral may continue to leak even after the Insituform liner has been installed.

The Insituform lining of service lateral pipes done on the Missouri project was semi-experimental. Problems were encountered which have not yet been fully resolved. Better resins have recently been developed for this application which show promise. The ability to accurately position the Insituform liner has not yet been developed. In short, the process shows considerable promise, but more development work is needed.

4. Replacement

In the Missouri project, 22 service laterals were replaced for at least half their length. In some places, replacement is more permanent and less expensive than any other repair methods discussed. PVC sewer pipe was used for

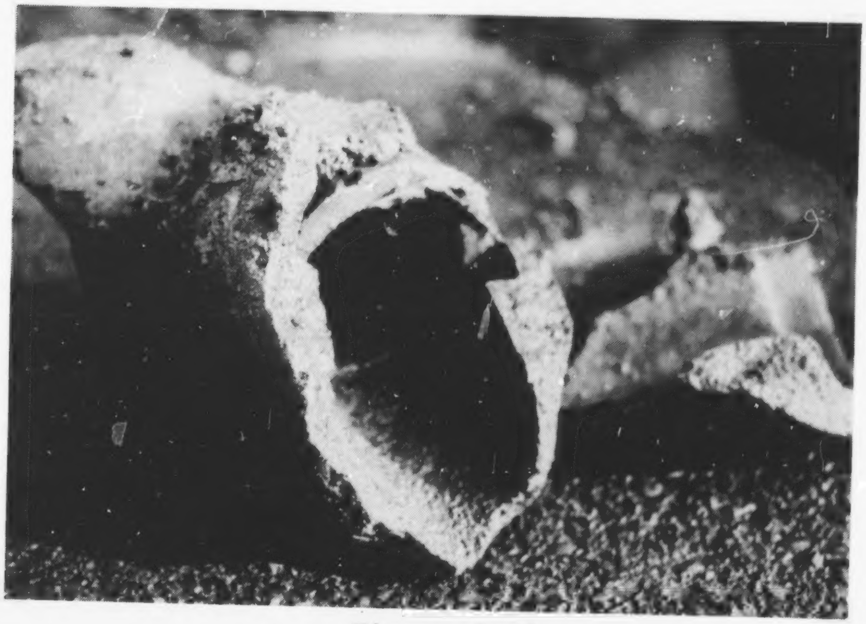


Figure 6-22
Broken Fitting

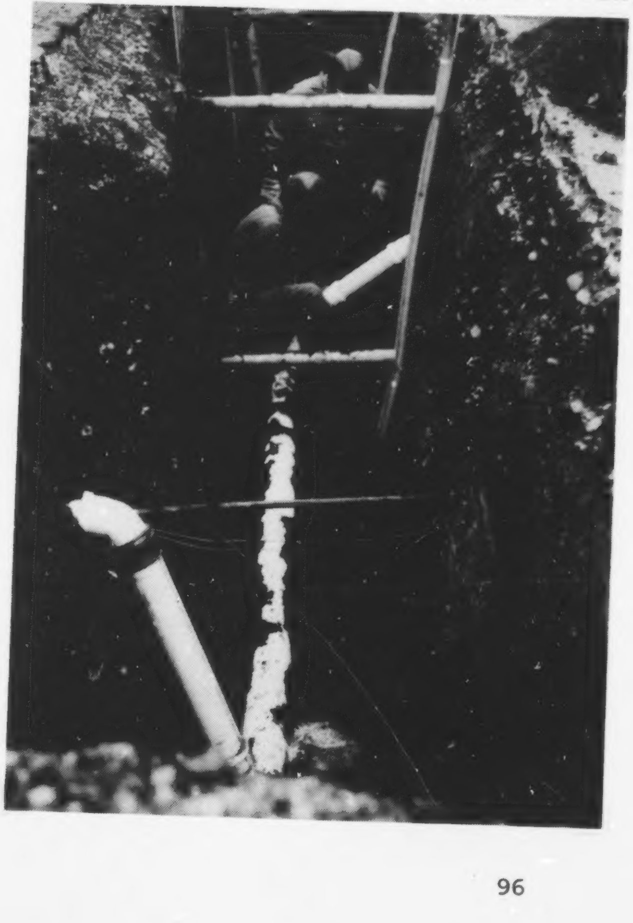


Figure 6-23
Why do configuration #1 services have broken risers? Answer: No support

service lateral replacement and mainline tee replacement. Many configuration #1 and #2 tee connections were badly broken. In most cases, a section of sewer main was uncovered and removed. A new PVC tee was then cut to fit and coupled in place with Fernco or Caulder couplings. These are rubber band on couplings available at most plumbing supply businesses. Where sewer mains and service laterals are not excessively deep, replacement of all or portions of the faulty installations are an important part of the sewer rehabilitation process. Approximtely 50 short replacements of service lateral piping were made. Many of these involved replacing a damaged fitting, removing an obstruction or replacing a misaligned joint.

TABLE 6-4
SERVICE LATERAL REPAIR METHODS

1.	Grout using snake	$375	1. Can seal laterals with a few leaking joints reasonably inexpensively. 2. Minimal excavation required.	1. Limited to structurally sound pipe. 2. Life of repair may be limited.
2.	Grout using Cues Lateral Sealing System	$575*	1. Access is from within main. 2. Testing and sealing accomplished in single operation. 3. Inexpensive because access is from within main.	1. Can only test and repair lower six to eight ft (1.83m 2.44 m) of service lateral. 2. Availability for eight ft (20.32 cm) mains only. 3. Lateral work is done blind, can not determine if pipe is broken, etc. 4. Sock will not advance up some service laterals with radical bends, etc.
3.	PE Liners	$575	1. Positive, long lasting repair. 2. Relatively easy to install liners. 3. Minimal excavation required.	1. Requires excavation on at least one end and usually requires two or more excavations. 2. Existing pipe needs to be relatively straight.
4.	Insituform Liners	$2,300	1. Can be installed where access poor and existing pipe is poor. 2. Long lasting repair. 3. Minimal excavation required.	1. More development work needed. 2. Relatively expensive.
5.	Replacement	$750-$1,500	1. Permanent. 2. Can be utilized where others cannot.	1. Excavation required.

Costs are based on having a contractor do the work.

*Experience of Washington Suburban Sanitary Authority

G. COSTS

Table 6-5 shows the breakdown of labor, materials and equipment for various phases of the service lateral testing and repair program conducted in the Missouri Basin. All work except tee tests and repairs was done by Gelco Grouting Service. Most work was done on an hourly basis utilizing hourly rates for labor and equipment. Materials were supplied at their purchase cost.

Without explanation, some costs shown on Table 6-5 will be misleading. The installation of cleanouts was done mostly by hand. Two laborers hand dug the holes for the cleanouts, sawed out a section of service lateral pipe, and installed a new PVC cleanout. Some service laterals required more than one cleanout because of bends in the piping.

About 25 of the digups and spot repairs were made for access alone. Service pipes, usually near the property line, were dug up and sectioned so that service lateral TV inspections and air tests could be made. Other digups and spot repairs were made where some specific fault had been discovered and needed to be repaired. The labor and equipment shown includes the excavation and backfill required, but does not include costs for repaving or resoding.

Early in the program, all service laterals with cleanouts were cleaned prior to TV inspections. A high pressure hydrocleaner with a special nozzle was used.

TV inspections utilized a small diameter TV camera. Some service laterals were inspected more than once for various reasons. A few were never TV inspected. Likewise, some service laterals were never air tested, while others were air tested more than once.

Forty-three service laterals were repaired at least in part using the Westech/Gelco snake. Twenty-seven service laterals were substantially repaired using the snake. The costs shown include both types of operations.

The Cues Lateral Sealing System and the Insituform liners were installed at pre-established unit prices. Both of these operations were considered by Gelco to be somewhat experimental as their personnel had no previous experience with these operations. The manhours, equipment, time and materials used with the Cues Lateral Sealing System and the Insituform liner installations could not be accurately determined.

TABLE 6-5
MISSOURI SERVICE LATERAL TESTING, INSPECTION AND REPAIR TESTS

	QUAN. DONE	MANHOURS/ COST	MATERIALS	EQUIP HRS/COST	TOTAL COST	UNIT COST
A. Cleanouts	54	150 $4,136.22	$1,157.47	Flatbed Truck - 73 Backhoe - 6 Dump Truck - 6 Concrete Saw - 73 $1,812.70	$7,106.39	$131.60
B. Digups and Spot Repairs	57	247 $6,897.85	$649.19	Flatbed truck - 83 Backhoe - 73 Dump Truck - 63 Concrete Saw - 75 Compressor - 18 $4,512.70	$12,059.74	$211.57
C. Clean Service Laterals	54	101 $3,322.90		Hydrocleaner - 50.5 $2,020.00	$5,342.90	$98.94
D. TV Inspections	95	186 $6,130.10		TV Van - 70 Mini Camera - 100 Pickup Truck - 27 TV Combo Unit - 4 $9,479.20	$15,609.30	$164.31
E. Air Tests	78	97 $3,191.31		Truck - 64.5 Double Ball Test Trailer - 64.5 $2,476.50	$5,665.81	$72.66
F. Grout Lateral Using Snake	43	204 $6,733.00	$1,417.50	Grouting Van - 96 Pickup - 35 Snake Grouter - 104 $7,838.30	$15,988.80	$371.83
G. Cues Lateral Sealing System	7 sealed 4 attempts to seal		$600/ea.		$4,200.00	$600.00

TABLE 6-5 (CONT.)
MISSOURI SERVICE LATERAL TESTING, INSPECTION AND REPAIR TESTS

	QUAN. DONE	MANHOURS/ COST	MATERIALS	EQUIP HRS/COST	TOTAL COST	UNIT COST
H. PE Liners	20	210 $5,849.98	$1,245.81	Flatbed Truck - 54 Backhoe - 51 Dump Truck - 50 PF welder - 49 Concrete Saw - 54 Compressor - 22 $4,363.25	$11,459.04	$572.95
I. Replacements	22	125 $3,483.00	$650.82	Flatbed Truck - 47 Backhoe - 47 Dump Truck - 42 Concrete Saw - 46 Compressor - 29 $3,268.35	$7,402.17	$336.46
J. Insituform Liners	6		$2,300 ea			
K. Tee Tests and Repairs*	77				$7,402.17	$336.46
L. Misc					$27,738.85	

* By City crews. Labor and equipment charges at rates well below industry average.

Twenty PE liners were installed. This work is labor intensive. The costs shown do not include the cost of sealing the lower end of liners into the existing piping. Those costs are included in Item K, Tee Tests and Repairs.

The costs for pipe replacements is particularly misleading. Many of the replacements were very short. Included in the replacement costs are 13 very short replacements, less than 10 ft (3.04 meters) long. Three service laterals were replaced from the house to the main, and they cost an average of $745.00.

The tee tests and repairs were made by City crews at labor and equipment rates averaging about half of those charged by Gelco. The tee tests and repairs include the sealing of many PE liners into the existing service lateral.

Many small tasks did not neatly fall into other categories. Cleanup work, surface restoration, resoding lawns, responding to citizen questions and complaints, digging to locate service piping, etc. are some tasks included in the miscellaneous category. In all, approximately $137,600 was spent on testing, inspecting and repairing 86 service laterals. Every service lateral required some repair. The average cost of this operation was $1,600 per service lateral. Because this was a demonstration project, some methods were used and some work was done which would not normally be done.

H. SUMMARY

When the Missouri Rehabilitation Project was reactivated in the fall of 1983, plans were made to repair all service laterals in certain areas using one access and repair technique in each area. Often, this did not prove to be feasible. The conditions found at each service lateral location vary considerably. The types of pipe, alignments, and surface conditions differ. Different techniques to access and repair piping was often necessary. In short, there is no single "best way" to access, test or repair service laterals. Rather, several types of access and repair techniques are needed for the testing, inspection and repair of service laterals in any sewer basin similar to the Missouri Basin.

Where service lateral repair from house to main appears necessary, cleanouts for access are especially advantageous. The cleanouts can be installed initially, and then serve as access throughout the entire rehabilitation project. Service lateral reinspection after initial repairs have been made is sometimes necessary. The cleanout allows this.

Where service lateral repairs need to be made from main to property line only, digups or the Cues method for access have some advantages. Digups are difficult only in that they usually cannot be left open very long, and this makes scheduling of the testing and repair work more difficult. The Cues Lateral Sealing Unit is particularly applicable in relatively new systems, systems installed within the last 20 years or so where service lateral piping generally is in good structural condition. Using the Cues equipment on the Skyline Project would have been better than its application to the Missouri Basin Project. Where sewer mains are deep, or access to the service laterals is poor, the Cues Lateral Sealing System is particularly applicable.

Where virtually all service laterals are faulty, it may not be necessary to TV inspect or air test, particularly if the services are to be replaced. If PE liners are to be used, TV inspections to determine whether the lines are straight enough for the liner installations may be prudent.

Where private property owners are responsible for the piping on private property, the Sewer Agency must perform tests if repair or replacement of the private piping is to be required. If grouting with the Westech/Gelco snake, PE liners or Insituform liners are being considered as a rehabilitation technique, TV inspections and perhaps air tests usually will be required. If air tests are necessary, the least expensive and most positive service lateral testing equipment is the double ball test apparatus.

Use of either the Cues Lateral Sealing System or the Westech/Gelco snake to grout service lateral piping is most applicable where the service piping is relatively new and most joints are watertight. The life expectancy of grouted repairs has not been well established. Thus, if more permanent repairs or replacements can be accomplished without unusual difficulty and for near the same costs as grouting, the prudent choice is the more permanent installation. PE liners make good service lateral repairs. Where an entire service lateral is faulty and is without major obstructions or bends, PE liner can be installed with relative ease and without great expense. If properly installed, the PE liners should provide long-term trouble free service.

Insituform liners show great promise. If the unresolved technical problems can be solved, the process can permanently rebuild almost any service lateral, regardless of how faulty or inaccessible it is. These liners may always be relatively expensive. Nevertheless, where service laterals lie beneath busy streets or highways, are under buildings or at great depth, Insituform liners may offer the best rehabilitation option.

Every service lateral tee connection on the Missouri Project and many connections on the Skyline Project were found faulty and needed repair. The service lateral pipe immediately adjacent to the main can contribute much I/I. Thus, the testing and repair of these connections is particularly important. The Cues Lateral Sealing System and the Plug and Test Method can both repair this portion of the service lateral pipe. If each service lateral has upstream access, the Plug and Test Method has some advantages. The tee testing and repair can be done along with main sealing and with the same equipment. If there is no service lateral upstream access, then the Cues Method is preferred.

The importance of service lateral repairs has been well demonstrated. In many sewer systems, significant I/I reductions cannot be achieved without repairing faulty services. The methods, techniques and equipment available for service lateral testing, inspection and repair today have been developed the last few years. As more service lateral repair work is done, new methods, new equipment and better efficiencies will result and, hopefully, the cost of these operations can be reduced.

Until recently, little work has been done in finding, accessing and repairing service laterals. The experience gained from repairing service laterals in sewer systems in other cities and in other climates and soil conditions will undoubtedly add considerably to the lessons learned in Salem. Additionally, because this endeavor is new but has already gained widespread interest, new equipment and techniques surely will be forthcoming.

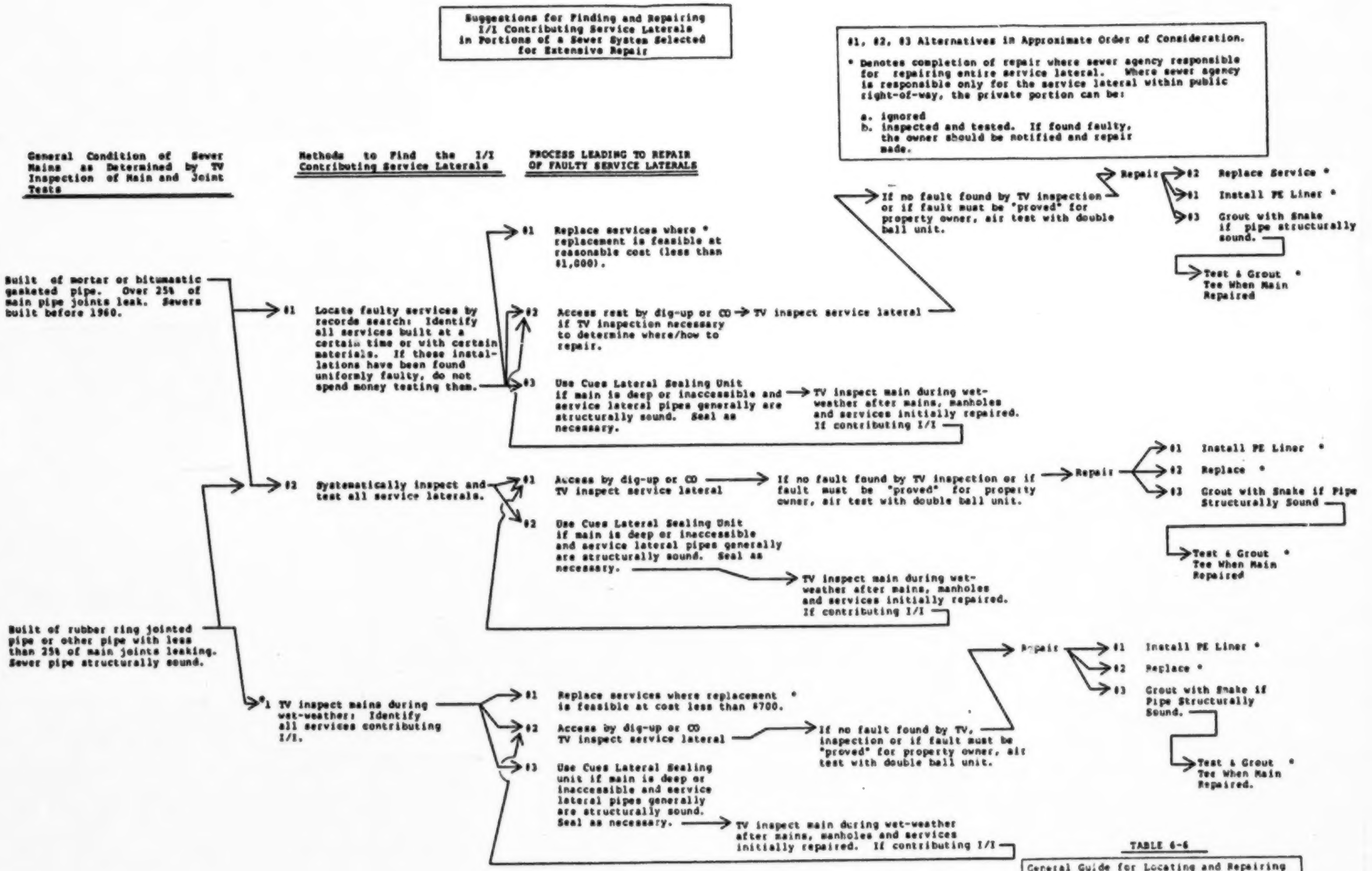
The experience gained to date indicates that:

a. In older, mortar jointed sewer systems, virtually all service laterals are faulty. Nearly all are faulty at their connection to the main, but most are faulty elsewhere also. Many must be repaired if I/I is to be significantly reduced.

b. In newer, rubber ring jointed sewer systems, or systems where most of the mains are reasonably watertight, usually less than 50% of the service laterals contribute significant I/I. In these systems, the systematic testing of all service laterals is an unnecessary expense. A more selective approach is usually warranted.

There are many variables to be considered in determining how to best find the I/I contributing service laterals and to repair them. There are no simple answers. Each sewer main and each service lateral must be individually evaluated and the most expedient and practical methods employed. Table 6-6 offers a general outline of how to go about finding and fixing the "leakers." It is not applicable to all sewer systems or situations, but is intended only as a general guide. It presumes that roof drains, yard drains, footing drains, and the like have been previously discovered and disconnected. Use the table with caution.

Suggestions for Finding and Repairing
I/I Contributing Service Laterals
in Portions of a Sewer System Selected
for Extensive Repair


General Condition of Sewer Mains as Determined by TV Inspection of Main and Joint Tests
Methods to Find the I/I Contributing Service Laterals
PROCESS LEADING TO REPAIR OF FAULTY SERVICE LATERALS
Built of mortar or bitumastic gasketed pipe. Over 25% of main pipe joints leak. Sewers built before 1960.
#1 Locate faulty services by records search: Identify all services built at a certain time or with certain materials. If these installations have been found uniformly faulty, do not spend money testing them.
#1 Replace services where * replacement is feasible at reasonable cost (less than $1,000).
#2 Access rest by dig-up or CO if TV inspection necessary to determine where/how to repair.
TV inspect service lateral
If no fault found by TV inspection or if fault must be "proved" for property owner, air test with double ball unit.
Repair
#2 Replace Service *
#1 Install PE Liner *
#3 Grout with Snake if pipe structurally sound.
Test & Grout * Tee When Main Repaired
#3 Use Cues Lateral Sealing Unit if main is deep or inaccessible and service lateral pipes generally are structurally sound. Seal as necessary.
TV inspect main during wet-weather after mains, manholes and services initially repaired. If contributing I/I
#2 Systematically inspect and test all service laterals.
#1 Access by dig-up or CO TV inspect service lateral
If no fault found by TV inspection or if fault must be "proved" for property owner, air test with double ball unit.
Repair
#1 Install PE Liner *
#2 Replace *
#3 Grout with Snake if Pipe Structurally Sound
Test & Grout * Tee When Main Repaired
#2 Use Cues Lateral Sealing Unit if main is deep or inaccessible and service lateral pipes generally are structurally sound. Seal as necessary.
TV inspect main during wet-weather after mains, manholes and services initially repaired. If contributing I/I
Built of rubber ring jointed pipe or other pipe with less than 25% of main joints leaking. Sewer pipe structurally sound.
*1 TV inspect mains during wet-weather: Identify all services contributing I/I.
#1 Replace services where replacement * is feasible at cost less than $700.
#2 Access by dig-up or CO TV inspect service lateral
If no fault found by TV, inspection or if fault must be "proved" for property owner, air test with double ball unit.
Repair
#1 Install PE Liner *
#2 Replace *
#3 Grout with Snake if Pipe Structurally Sound.
Test & Grout * Tee When Main Repaired.
#3 Use Cues Lateral Sealing unit if main is deep or inaccessible and service lateral pipes generally are structurally sound. Seal as necessary.
TV inspect main during wet-weather after mains, manholes and services initially repaired. If contributing I/I

#1, #2, #3 Alternatives in Approximate Order of Consideration.

* Denotes completion of repair where sewer agency responsible for repairing entire service lateral. Where sewer agency is responsible only for the service lateral within public right-of-way, the private portion can be:

a. ignored
b. inspected and tested. If found faulty, the owner should be notified and repair made.

TABLE 6-6

General Guide for Locating and Repairing
I/I Contributing Service Laterals

I. RECOMMENDATIONS FOR NEW CONSTRUCTION

After having repaired and replaced numerous service laterals, and after seeing how much I/I is sometimes contributed by service laterals, several problem areas become apparent. Most can be eliminated or reduced, some at little expense, by changed or improved service lateral construction requirements.

There are three overriding problems encountered in dealing with service laterals:

1. Faults in the service laterals themselves.
2. Lack of access to service laterals so that faults can be discovered and repaired.
3. The divided responsibility between the sewer agency and the property owner for the service lateral.

Most service lateral faults and the changes required in new construction to remedy them are listed below:

1. Broken or faulty connection at mainline tee or wye. It is very difficult to get adequate support under a main tee or wye and the first joint of service pipe. Some movement at this joint is likely to occur, regardless of the measures taken to prevent movement. This connection needs to be flexible so that differential movement can occur between the main pipe and the service lateral without a leak resulting.
2. Broken or faulty risers (See Figure 6-1). Configuration 1 should not be allowed. As a maximum, risers should be no steeper than 45 degrees from the horizontal so that the riser pipe is supported by undisturbed soils.
3. Faulty piping and joint materials. Some pipe materials used in the past which resulted in many faulty service laterals are no longer available. Service lateral pipe needs to be strong, durable and watertight. Flexibility is a desirable quality also. The following service pipe materials have been found to be generally acceptable:

   Cast Iron, Class 150, ANSI 21.1
   PVC, SDR 35, ASTM 3034
   PVC, SDR 41, ASTM F789/D3212

4. Lack of adequate regulations or inspection. Some service laterals have been found which were installed so poorly that no regulations or inspections could have been applied to them. Each sewer agency should have regulations establishing allowable pipe materials for service laterals, procedures for permits and inspections, leakage allowances and installation specifications. Each service lateral pipe should be inspected and tested for leakage before being placed in service. The sewer agency should map and record all service laterals.

Adequate access to new service laterals can be established by:

1. Requiring a cleanout as shown in Figure 6-2 be installed adjacent to each building served and at all pipe bends 45 degrees or greater.

2. Having a stipulation in the agencies sewer ordinance allowing agency personnel to use private cleanouts upon proper notice for the inspection, testing and/or repair of any part of the service lateral.

3. Allowing no bends in service lateral pipe to be greater than 22 1/2 degrees without a cleanout immediately upstream except for a single 45 degree vertical bend within 10 feet (3.05 meters) of the main.

4. Allow no service lateral piping smaller than 4 in. (10.2 centimeters) diameter. The same sized pipe must be used from main to building.

Some sewer agencies accept no responsibility for service lateral piping. They make the property owner responsible from main to building. Other agencies accept responsibility for the service lateral from main to property line and make the property owner responsible for the rest.

To date, the City of Salem has paid for the repair or replacement of all service lateral repairs in both the Skyline and Missouri Basins. This was done because of the experimental nature of the two projects. Salem normally holds the property owner responsible for the entire service lateral, from main to building. Probably few repairs would have been made had the City tried to require each property owner to repair his service lateral from the main in the street. Most property owners are not financially able, technically able or much inclined to make such repairs.

Two programs in other cities have shown that there is a way to:

1. Get faulty service laterals repaired or replaced adequately.

2. Obtain property owner and public official cooperation in doing so.

The programs have the following features:

1. The sewer agency is responsible for service laterals in public right-of-way and property owners are responsible on private property.

2. The sewer agency notifies property owners that service laterals will be tested and inspected on a certain date. The property owners are given the opportunity to contract with the Agency for any repairs on private property found necessary. A maximum cost is set which is quite advantageous to the property owner.

3. The sewer agency does a competent job of selling the program to property owners. There are efficiencies in making both private and public repairs to a service lateral at one time. If the Agency makes the private repairs, the costs and delays involved in notifying property owners of faults, enforcing the repair ordinance and making inspections of repairs are avoided.

4. As private repairs are made by the Agency or the Agency's contractor, the actual costs up to the preset limit are billed to each property owner. They are given the choice of paying at once or paying a monthly surcharge on their sewer bill until the charge is paid off.

5. Those property owners not electing to contract with the Agency for repairs are notified if faults are discovered in the private service piping. They are given a reasonable period (60 days) to make the needed repairs. If the faults are not repaired in the prescribed time, the service lateral is declared "non-conforming" and a special monthly service fee, usually

twice the normal fee, is charged until the repairs are made.

This program is presently being used and is one reasonably successful program for consolidating the responsibility for service lateral repairs so that sewers can be successfully rehabilitated.